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DISCOVERY

A POPULAR JOURNAL OF KNOWLEDGE

Edited by C. P. SNOW

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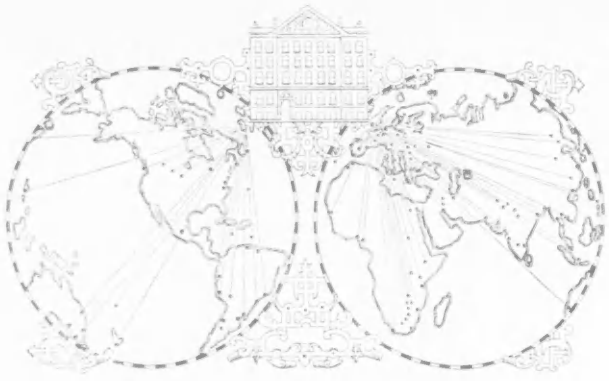

NEWS FROM ABROAD

THERE are 299 countries listed in an up-to-date Atlas. How is a daily newspaper to deal with the events in all of them? The methods adopted by different newspapers vary. One method is to ignore the outside world until circumstances force some particular place "into the news." Then, perhaps, a famous correspondent may be sent post-haste to investigate, to gather and report his impressions on the spot.

A different method is that established long ago and still followed by *The Times*. This is to maintain a permanent staff correspondent in every important centre, with a chain of local correspondents to keep him in close touch with every part of his area.

This system is expensive and not at all spectacular. But it has incalculable advantages for the reader of *The Times*. He is kept *constantly* informed of all that is going on—of what is being done and said and thought—in all parts of the world. He never loses touch.

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THE TIMES

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SCIENTIFIC PROPHECIES

ONE of the fascinations of science is that no one can deny its progress. In every other human activity, the past-minded can put up some sort of case; it is probably quite unreasonable to pretend that W. G. was a batsman of the same class as Bradman, but the opinion cannot be dismissed as self-evidently absurd. The same is true of the opinion that literary achievement reached its height in Athens 2400 years ago, or at any rate at no period more modern than the sixteenth century; or that painting died with Rembrandt; or that we have forgotten how to build since the Georgian architects put up their last squares.

Perhaps those who believe these things do so because they are homesick for the past. Nevertheless, they do not at once lose the right to be taken seriously; while anyone who advanced the view that modern science is inferior to that of a past century would prove himself to be either crassly ignorant or mentally unstable. No sane and informed person doubts that our scientific picture of the world is richer and more accurate than it was fifteen years ago—and that in fifteen years' time it will be much richer and more accurate still. That *certainty* of progress freshens the air which scientists breathe, and, though they are often past-minded outside their work, it enlivens them and assures them that they are not wasting their lives.

Even to-day that certainty still holds. Many of us think that we are living in a twilight world, in which soon the best things will be darkened for a time. Even so, many parts of science are as certain to make progress as they were in 1900. Whether this civilization escapes its dark age or not, science will continue its advance, less affected than one sometimes likes to think. The phrase "dark age" brings to mind a misleading analogy; for, with the fall of the Roman Empire, it was not only mental achievements that were lost, but material also; the world in A.D. 800 was technologically more backward than five hundred years before (roads and sanitation, for example, were far less good).

If our own dark age occurs, it is highly unlikely that that kind of retrogression will be part of it. Mental obscurantism may overtake us, perhaps more likely than not: but organized science has become part and parcel of a material civilization so intricate, so widespread and so tough-rooted that the world cannot get rid of either.

Art and literature will suffer in a new dark age and the open thinking that we take so much for granted, although most men have only enjoyed it for a couple of hundred years; those sciences which are too far from technological progress, such as mathematical physics, or too near politics, such as pyschology, anthropology and economics, will suffer also. But the main progress of science will not be stopped. It may be slowed down, because you do not get the best applied results out of science unless you set it free to follow its own course in fundamental theory at the same time. But it will not be stopped.

Whatever happens in the next twenty years in Europe, science will be more advanced than it is now. In particular, applied science will have added to our material civilization, and medical knowledge will have grown even more than it did between 1900 and the present day.

This certainty of progress makes science the most satisfactory subject to prophesy about. You have not the fear at the back of your mind that you ought to allow for an advance backwards, so to speak. And of all prophecies in this century, compare H. G. Wells's in his detailed short-scale scientific forecasts with anyone's attempts in any other field. Prophets ought to keep a score: plus one for a successful prophecy, minus one for a prophecy that proves absurd. Wells's *Anticipations*, published forty years ago, would show a handsome positive balance on this method of marking; most prophets come out of it very badly.

Discovery is beginning the year 1939 with a piece of scientific prophecy by Mr Courtney Bryson. Mr Bryson's predictions are based on our rapidly growing knowledge of plastic materials. This is a good example of an applied scientific field which is unlikely to be upset by changes in the world. More than most of us, Mr Bryson has the chance of returning a positive prophetic score at the end of the period he covers. In February we publish a sequel by Mr Bryson, dealing with advances in other materials. During the year we intend to present several articles on the progress of science in the foreseeable future.

SYNTHETIC PLASTICS

Their Influence on the Future

By H. COURTNEY BRYSON

IN the beginning was the Stone Age. Then came the Metal Age. At the commencement of this century Dr Baekeland commercially perfected the action of carbolic on formalin to produce the synthetic resin. This was the inauguration of the Synthetic Plastic Age. It is not perhaps generally realized that even in our present age synthetic resins and allied substances are the pins which hold the fabric of civilization together. In the future, as I shall show, they will so increase in importance that they will be more of the nature of the fabric of civilization itself, rivalling and outclassing metal in consumption.

Materials Made to Order

Indeed, in the future, we shall be able to make materials to specification. Professor Goldschmidt, of Oslo, has shown that it is possible to copy existing molecular structures with other atoms, making the new substance have different properties. The material known as carboloy is an example. Thus it is not impossible that we may be able to create a cheap material, capable of being moulded or cast at a low temperature and then hardened, with the combined properties of diamond and steel, i.e. the transparency, hardness and resistance of diamond with the resiliency, strength and cutting properties of steel. When we have done this, the words "plastics" and "metals" will cease to have meaning. We shall construct our instruments and our homes, roof over our nightless cities, and build our aeroplanes and our space-planes from such materials.

Any attempt at prophecy must, of necessity, be based upon the unsound premises that the alterations which will occur in the future will be more of degree than of kind; or, as Byron puts it, "the best of prophets of the future is the past". This, of course, is not so. We can only be certain that the future will be much more wonderful and unexpected than any speculation concerning it, for changes will come about which are outside the imagination.

In attempting to give a few disjointed pictures of the probable influence of plastics in the future, I assume, probably quite falsely, that the present Renaissance (which is packing our colleges and making fortunes for technical booksellers) will continue; that human nature will not greatly alter for a considerable period; and that our civilization will endure. It is far more probable that when the present, almost universal, thirst for knowledge is spent, the incentive for truth and research for its own sake will die with it, as it has died in the past; or that the fifth or sixth world war from now will sweep us back into barbarism if not to annihilation.

Let us hope that before this occurs biology will have perfected ectogenesis and germ-plasm control and that psychology will be transformed to psychonomy, so that the two sciences working together will be able to produce a new species of the genus *homo*, more adaptable, less martial, and more rational than the present species of *homo sapiens*—a creature less endowed with limbs than the lowest insect, less agile than any inhabitant of the jungle, ugly in most cases and an animated museum of useless vestigial remnants.

Research is the Enemy of Stability

The increasing acceleration of change, which is the keynote of the world today, is due to the fact that research is the enemy of stability. Consequently, we are now living in an age of violent instability. This was realized during the early part of the nineteenth century when the inventor was denounced as a public enemy.

No living creature, as far as we know, lives under changing conditions without undergoing the profoundest changes itself and, as already pointed out, we are at the beginning of the greatest change that humanity has ever undergone.

I shall not attempt to discuss the improvements in detail which are certain to occur in the immediate future, and which are contained implicitly in the forces operating in the present and are not difficult of interpretation. Thus the greatest development in artificial resins will occur in other than the phenol-formaldehyde type, which seems to have reached a stage equivalent to that of the railway engine which has remained almost stationary—in the strictly metaphorical sense—for a decade. We appear to be at the same sort of limit with phenol-formaldehyde resins, and there will probably be no striking innovations.

Neither shall I attempt to describe the effect upon humanity of the synthetic sausage skin, edible and odourless; nor to delve deeply into instances where moulded articles will replace other materials, growing ever larger in quantity as well as size, so that we shall soon be sitting on moulded chairs, at moulded tables, eating off moulded plates, while we throw the scraps to dogs with moulded collars, living in moulded kennels. Mere increase in size is not true novelty. We limit or increase our size solely for convenience. Moulded gas-holders or railway carriages would be interesting, but they would not be true inventions.

Since communication is the essence of civilization, I will commence with a few notes upon roadways.

Scarcely anything has more care and attention lavished upon it than the modern road. It is an outward and visible sign of an inward and diverse complexity. It extends hither and thither, entering each life and almost each action. It is laid down with care and rolled with precision. We try and make things easy for the road by cutting off corners and levelling it out. We harden its surface and render it waterproof. We wash it and dry it. We hedge it about and make laws concerning it.

We illuminate it and try to beautify it. We dig little tunnels near it and use them to supply water and gas and electricity, and carry away waste products. Lastly, we tear it up in order to furnish jokes for comic papers. Such is our present-day road.

The Roadway of the Future

The roadway of the future will not be one whit less important than that of to-day, even though aerial traffic bears an increasingly great load. The unpleasant hardness and cracking of concrete, the short life of the wood-block surface, the cold flow and seasonal variation of the bituminous surface, and the disadvantages of rubber will probably be overcome in the future by the adoption of some form of synthetic resin as the surfacing material.

It is extremely unlikely that anything much better than concrete will ever be discovered for the foundation. On this ferro-concrete bed, suitably keyed, will be laid a compound with a synthetic resin base, which will have the same coefficient of expansion as the concrete. The peculiarity of the resin will lie in the fact that it will polymerize under the action of ultra-violet rays instead of the more usual action of heat.

Laboratory experiment amply demonstrates that this can be achieved. Furthermore, the principal filler of the resin will be an abrasive substance of sufficient hardness to form a suitable grip for the wheels, however wet the road. The proportion of this abrasive will be so adjusted as to wear evenly with the resin, and present a constant surface of the proper degree of roughness. Further novelty will be introduced by the incorporation of a luminous material. The mixture will be loaded into huge tanks on wheels in the dark, and then extruded during the day from slot-like orifices situated as a fan in the rear of the vehicle, followed by a gigantic levelling-off knife, the shape of the camber of the road. Bright sunlight would harden the resin in 20 minutes. A dull day would require twenty or thirty times this period.

A Red-hot Hair-pin inside a Glass Bottle

This road will benefit everybody. Its hard, impermeable and weather-resisting surface will never suffer from cold flow, however many lorries try to push it into transverse ridges. The resin will never crack. Its crushing strength will be high, its surface always be uniform, and at night it will save the ratepayers money for illumination. In any case our present means of illumination, by means of a red-hot hair-pin inside a glass-bottle, stuck on a pole, is so inefficient that it is bound to die out. 90% of the energy is wasted.

On this road surface even a mouse will show up. The air pilot, too, will find night-flying greatly simplified; the darker the night the more easily would the sinuous routes be distinguished, and towns would be recognized by the character of the roads leading to them.

From the subject of the road it is natural to pass to the vehicle which uses it. Moulded vehicle wheels will be produced in the near future. They will be lively and resilient; they will not need painting; they will not tarnish or corrode like metal wheels or crack like wooden ones.

Safety-glass

This decade has seen the rise of several types of synthetic glass. It is probable that in the near future safety-glass as such will be substituted by a water-white non-discolouring resin possessing sufficient surface hardness to withstand abrasion by suspended dust particles and with the additional property of sufficient initial plasticity to be shaped into aesthetically satisfying curves. Researches along these lines are being pursued by manufacturing the resin and bending it before case-hardening the surface by brushing it with a special hardening agent. This new "glass", or modifications of it, will find increasingly large use. Lenses, with any desired index of refraction, will be produced. Indeed, moulded lenses, cheaper, clearer, more highly corrected are now being made.

Tyres

Tyres consume the major part of the world's rubber supply. It is probable that, but for the policy of self-sufficiency for nations, the rise of synthetic rubber would have been much slower, since advances in plantation cultivation and the use of other latices are likely to lead to increasing yields and lower costs. Chlorinated rubber containing 66% of chlorine is probably one of the most inert organic materials known since it resists both strong acids and alkalis. It is thermo-plastic and may be moulded and it can also be used as a surface coating material. Other halogenated derivatives of rubber will probably find increasing use in the near future.

The X-ray investigation of linked molecules, which constitute complex elastic substances, will, when their nature is thoroughly understood, lead to the synthesis of new substances with different properties, able to withstand more rigorous conditions of service and be more widely adaptable to increasing needs. Whether these will provide us with an artificial leather depends entirely on whether we can manufacture the substitute more cheaply than Nature can produce it.

Artificial Wood

In the not very far distant future there is bound to be a great change in our use of the material which, though not classed as a plastic, has nevertheless served from the very earliest time as one of the most beautiful as well as one of the most adaptable of substances. I refer, of course, to wood. European demands exceed the annual growth of soft woods by approximately three thousand million cubic feet. The bulk goes to the paper trade where, incidentally, the world is still waiting for a successful method for the removal of ink from newsprint. The plastic trade

consumes 4000 tons of wood dust per annum for mouldings, and the cellulose ester trade many times this amount. Hard woods are increasing in price.

Many attempts have been made to discover a material as cheap as wood and as capable of being transformed as easily into the same infinite diversity of shapes. The first really successful results will be achieved by using a wood waste of some sort. "Plastic wood" (sawdust and cellulose nitrate solution) is an example of an attempt in this direction. Claims for artificial wood, made by the internal disruptive explosion of wood waste, are being made in America. Whatever the ultimate solutions, for there will be several, the raw material will always be of a cellulosic nature. Cellulose and its esters are beginning to come into their own.

Paints and Lacquers

At present the U.S.A. and Great Britain manufacture between them 200,000,000 gallons of paint of all kinds per annum.

In the near future lacquers will be used in the form of an aqueous dispersion or emulsion of synthetic resin, for our knowledge of interfacial liquid surfaces is rapidly increasing. It will therefore be possible to use emulsions for most purposes of this nature, for it is obvious that water is the cheapest and most efficient medium we possess. This paint will be used as a source of illumination by the incorporation of exceedingly active luminous pigments selected to give a spectrum range as nearly as possible identical with sunlight. The ceilings and the upper part of the walls of buildings will be treated with this paint which, activated by daylight, will continue glowing all through the hours of darkness.

The esters of silicon will be a second competitor. We already use the simpler silicon esters for binding rotten stonework. The ester decomposes on exposure, leaving a film of silica. The silica molecule is a strong and stable structure. It resists weather, as the sands of the seashore testify. Most organic compounds do not weather well. Bakelite is notorious in this respect. Most of the changes which I foreshadow will only be completely successful when we know how to make organic plastics as resistant as inorganic.

Water is the principal constituent of any living cell. Industrially water is just as important. Pure water is as scarce almost as radium. All water is contaminated with dissolved materials—chiefly "hardness", consisting of cations such as calcium combined with acid radicles (anions) such as sulphates and carbonates. Very recently it has been discovered that certain species of infusible and insoluble synthetic resins are capable of removing anions and cations from water by its mere passage through them, without undergoing serious change themselves. In other words, distilled water can be produced rapidly, cheaply, and in the cold. Vast world-wide plans are actually being made to put this discovery to use which, in affecting more or less profoundly almost every industry and every home, from railways and fabrics to motor cars and electric light, is one of the most important of the century.

The Swanscombe Skull

By ALVAN T. MARSTON, L.D.S. Edin.

FROM time to time, we hear of the remains of extinct elephants, rhinoceroses, etc., being unearthed in and about London during excavations for the foundations of new buildings. The entrenchments made during the recent crisis have exposed on commons and in open places around London sections of gravel deposits. These animal remains, and the gravels, can throw considerable light upon the ancient history of this island.

Gravel terraces in the Thames valley occur at three well-marked levels, at 100 ft. and 50 ft. above the level of the present river, and at about the level of the present flood plain. As examples the gravels of Clapham Common belong to the 100 ft. or High or Boyn Hill Terrace; those of Lavender Hill to the 50 ft. or Middle or Taplow Terrace; and those of Battersea to the Low or Flood Plain Terrace. These terraces were left stranded as the ancient Thames cut its bed from 100 ft. higher than it now flows, more and more deeply down to the present level. Each terrace is, therefore, a separate stage in the history of the river, and each terrace is documented by the remains of animals, and the implements made by the prehistoric men, who lived at the period represented by that particular stage of the river's history. These bones and implements differ for each terrace, and now after one hundred years of research, following the lead of Boucher de Perthes, a fair amount of knowledge has been amassed by which we may know, with tolerable certainty, what type of human being lived at each of these stages of the river's history.

The gravels at Swanscombe, in Kent, about nineteen miles from London Bridge, have been known to archaeologists for the past fifty years for their wealth of early stone-age flint hand-axes of the Chelles-Acheulean type, hundreds of thousands of which have found their way into collections throughout the world. Yet despite this richness of implements, never anywhere in the world had any bones been found under circumstances sufficiently satisfactory to make it possible to accept them as the authentic bones of the makers of Acheulean implements. Acheulean Man was unknown skeletally: he was known only by his implements.

The hope of many workers at Swanscombe that we might find part of a human skeleton of the makers of these many implements was fulfilled in 1935. Every week-end for two years I had been studying the deposits and collecting bones and implements in the Barnfield Pit, Swanscombe. On this occasion at the Pit, which was being worked commercially, I visited all the working faces as usual, to see what might be showing, and in a section from which the Middle Gravels only are being removed, I saw a bone in the face, 24 ft. below the level of the surface and about 6 ft. above a loam layer which we know as the Lower Loam.

It should be noted that just as we have seen that each of the three Thames terraces represents a separate phase in the history of the Thames, so at Barnfield we have a succession of stages, each of importance; these are known as the Lower Gravels, the Older Middle Gravels, the Later Middle Gravels and the Upper Gravels. It is therefore important for precise dating to recognize that the position of this bone was in the Middle Gravels.

On clearing round this bone I realized that at last the great moment had arrived. We had got Acheulean Man. It was a human occipital bone, the bone which forms the back and part of the base of

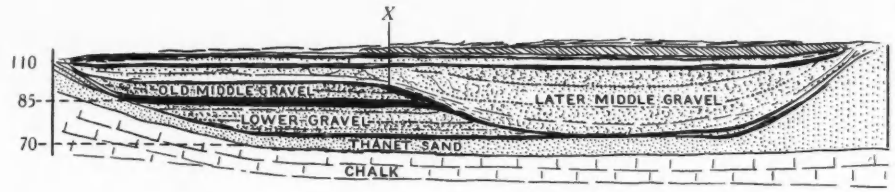


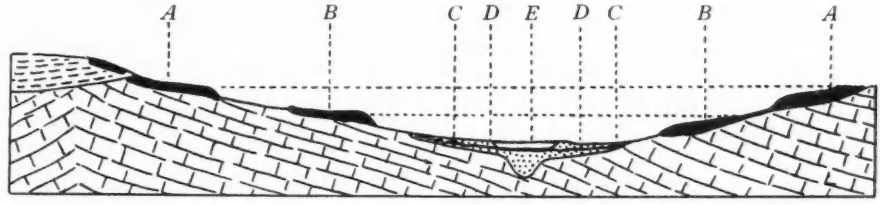
Diagram of the cross section of the Barnfield Pit, Swanscombe, showing the complex system of the deposits.

Note. Lower Gravels which yield Clactonian implements but contain no Abbevillian or Acheulean.

Older Middle Gravels which yield crude hand-axes of Abbevillian-Acheulean type.

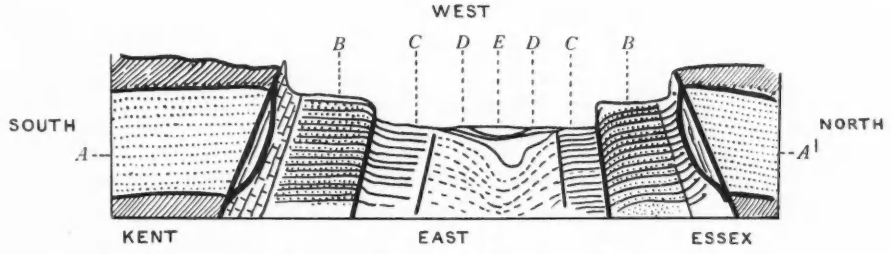
Later Middle Gravels which yield Acheulean implements.

X marks the position of the skull bones, at the end of the Older Middle Gravel Stage and the commencement of the cutting of the Later Middle Gravel Channel.



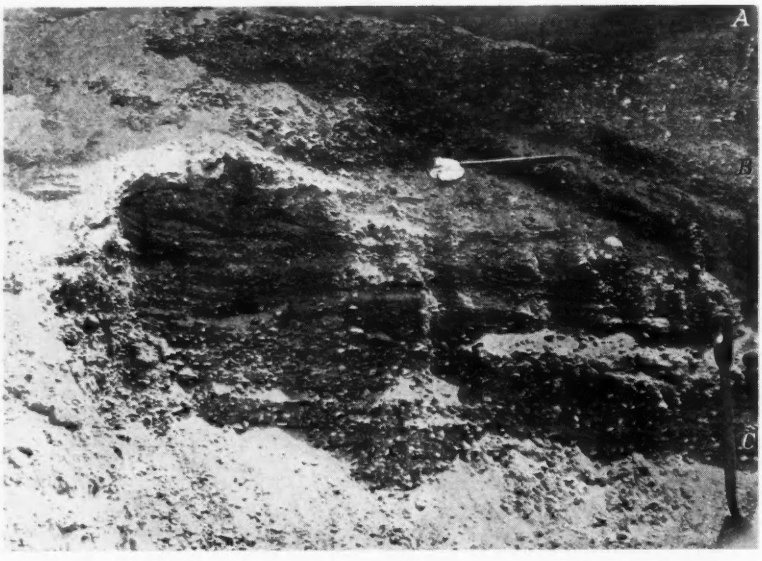
Hypothetical section across the valley of the Lower Thames between Kent and Essex.

A. 100-*ft. Boyn Hill or High Terrace.*
B. 50-*ft. Taplow or Middle Terrace.*
C. Flood Plain or Low Terrace.
D. Lower Flood Plain and Buried Channel.
E. River Thames of the present day.



Before the period when the precursor of the River Thames found its outlet to the sea by means of the present valley between Kent and Essex, and when it is believed to have flowed to the north by Ware in Hertfordshire, a river was flowing across the present Thames valley probably from south to north. In Barnfield and Ricksons Pits, Swanscombe, the channels belong to this ancient river bed which is shown at A and A[1]*. This river bed was washed away when the Thames broke through the Chalk at Goring and found a new outlet to the sea cutting the present valley of the Lower Thames.*

A. Gravels of the Barnfield River. These became masked by the Boyn Hill deposits.
B. Taplow Terrace.
C. Flood Plain Terrace.
D. Lower Flood Plain and Buried Channel.
E. Present River Thames.



Photograph (June 1935) showing the precise position of the occipital bone marked by the white object.

Note the oblique strata in the upper right corner, and the horizontal bedding below. This has given a precision to the skull horizon shared by but few discoveries of fossil Man.

the skull; it contains the "neck-hole" or foramen magnum, the large oval aperture through which the spinal cord is connected with the brain. It was in a state of practically perfect preservation, and was so complete that it gave us for the first time in a fossil of its age the complete foramen magnum, and the parts round it, the basilar process and the occipital condyles, or the pivots by which the skull is balanced upon the spinal column.

My first care was for the precious fragment; my second was to get the discovery properly recorded with as little loss of time as possible. The Geological Survey were informed. Sir John Flett, with Mr Henry Dewey, then Keeper of the Geological Museum, were supplied with full details and went down to Barnfield to view the site. When the bone was safely housed at the Geological Museum, Sir John wrote:

"The find is of paramount importance, and so far as I know is unique in having been recovered by competent hands from a known paleolithic level, and is also unique in being a fragment of probably the first Acheulean skull found in the world."

In September 1935 I was invited to exhibit the new specimen at the British Association at Norwich and to pass a few remarks as to its comparison with Piltdown and the Neanderthals. This revived the Piltdown controversy of twenty years ago. It soon became obvious that the Swanscombe bone was earlier than the Piltdown skull, and it became still more obvious that a colossal mistake had been made in maintaining that the fossil Ape's jaw found at Piltdown belonged to the bones of the Piltdown brain-case. Reasons for this different view are given at length in my paper on the Swanscombe skull (*Journal of the Royal Anthropological Institute*, vol. LXVII, July–December 1937).

The site of the Swanscombe skull in the Middle Gravels of the Barnfield Pit, Swanscombe. The post and the white object in the face mark the actual depth below the surface. Note the stratified nature of the deposits. The thick dense clay at the top and the Upper Gravel have been correlated with the Riss Glaciation. The gravels below them are therefore pre-Riss.

After working throughout the winter of 1935–6 we were at length rewarded in March 1936 by finding another bone of the same skull, this time the parietal bone of the left side. It, too, was in a state of perfect preservation, and it lay in the same seam of gravel about 24 ft. below the surface, but 8 yards farther into the deposits than the position of the first bone.

To understand the position, it must be realized that the gravels at Barnfield Pit are not quite the same as those terraces which we see in London, and which were flanking terraces of the River Thames. At Swanscombe they are actually the infilling of a separate river, 1400 ft. wide, i.e. nearly twice as wide as the Thames at London Bridge, and this river flowed before the present valley of the Lower Thames below Goring, with Essex on the north bank, and Kent on the south bank, had been excavated. It is believed that the Thames of this period, instead of entering the North Sea between Essex and Kent, then turned north through Ware, to pass through Essex or Suffolk. Thus the Swanscombe River was a much more ancient river than people had yet realized. It was formed certainly not later than the commencement of the second interglacial period which is known as the Mindel-Riss, and during the course of ages this river bed became gradually filled by the gravels which the river had transported and dropped to its bottom, and these gravels were laid down layer by layer. From the manner in which deposition occurred, one may infer that, throughout the greater part of this period, the general level of the land relative to the level of the sea was slowly sinking. Ordinarily when a river is carrying down quantities of gravel, the friction of the water-borne material scours and deepens its bed. It did not do this at Swanscombe. Instead, the heavy material was being carried and dropped without the bed being deepened,

and this suggests that the ordinary scouring action was being negatived by the subsidence of the land. The land sank faster than the river eroded, and the deposits piled up.

The various layers and the various stages in the infilling of the Swanscombe River each tell their own story as to the history of the river. In the Later Middle Gravels there are implements of a type which are not found in the Older Middle Gravels; in the Older Middle Gravels, again, implements of a type occur which have never been found in the Lower Gravels, and thus we have a well-marked evolutionary succession of implements made by Man, and may expect that evolutionary changes should affect the type of Man in the same manner as they affect the type of implement and the type of elephant and rhinoceros.

At the close of the period represented by the latest layers at Barnfield (when we bear in mind that subsequent ice ages have carried away some of the deposits from the top of the existing deposits so that the whole range of the sequence is not represented here now), the land still continued to sink, and a few miles away, at Dartford, where these later deposits are preserved, they were formed at a higher base level. The bed of the river which deposited them flowed as high as 135 ft. above the level of the present Thames, and it was not until this high-level Flood Plain was established that the valley of the Lower Thames between Essex and Kent was excavated.

This gives some idea of the antiquity of the Swanscombe skull. It was found in the infilling of an ancient river which had been in existence before the present mouth of the Thames had been formed, and it has consequently been judged that Swanscombe Man lived 250,000 years ago.

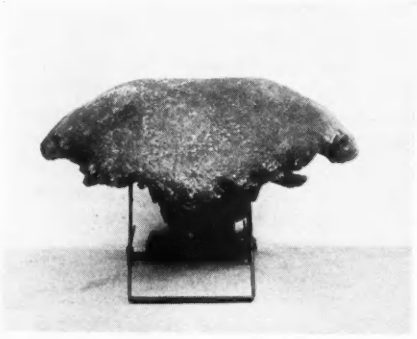
That the bones were found apart was due to the fact that they had separated in the river, one part being carried here and another 8 yards away, and it can only be hoped that the discovery of the other bones will occur within the limits of the area which remain available for examination.

The work to date has resulted in the carrying forward of our excavations for 50 yards on a 10-yard front and removing the sands and gravels in layers down to 24 ft. below the surface; this means that over 2000 tons of material have been examined; all the animal bones, every implement and humanly worked flake saved, and collections made of the river shells and other material for further research, so that although a considerable amount of valuable knowledge has been gained, there is still more of the skull to be got before we are satisfied.

The Skull

The skull is incomplete. The bones are those of a young adult of the middle twenties. This is shown by the condition of the free margins of the lines of union. For the time being, it must remain an open question whether it is a male or female skull. The muscles of the neck are vigorously marked; and one expert, who believed the Piltdown skull to be female, has given it as his opinion that the Swanscombe skull is male.

Is it *homo sapiens* or a Neanderthal? What does it matter? What does the label mean? What does *homo sapiens* mean? There are good reasons for expecting that the frontal bone of the Swanscombe skull will have the same heavy eyebrow ridges which have characterized all the really authentic types of Man from the Neanderthal type backwards. The back of the head is flat and thus differs from the "love-bump" type of the Neanderthal occipital bulge. But what must be remembered is that the Neanderthals belonged to the third interglacial, and Swanscombe to the second. Swanscombe is earlier than the Neanderthals, and should therefore be recognized as a pre-Neanderthal hominid. It shows primitive features which underlie both the Neanderthal and the *homo sapiens* type of skull form. It would be remarkable if it did not. If we were dealing with any other animal, say an Ape or Orang-outan, we should obviously admit that the young Ape



1. *Superior limit represents the linea suprema*

2. *Upper limit represents the linea inferior*

3. *Lateral view*

4. *Internal surface*

5. *Left parietal bone, external surface*

6. *Left lateral view*

SIX VIEWS OF THE SWANSCOMBE SKULL

skull-form underlies the adult Ape skull-form, even though there is so much dissimilarity between the female Orang-outan and the male.

So here, the simplicity of the Swanscombe skull should be recognized as a sign of primitiveness rather than as a sign of high organization. Indeed, the shape of the parietal bone is very reminiscent of the young infant human condition especially at the lower forward and hinder angles. In the modern skull, as the line of union between the frontal and parietal bones passes outwards from the top of the head, it sweeps downwards and forwards. If one sees such a skull from above, this line of union, the coronal suture, is crescentic, with the concavity directed forwards. In slightly more technical language the antero-inferior angle of the parietal bone in the modern skull is situated anteriorly and not directly below its antero-superior angle. In the Swanscombe skull the antero-inferior angle is below the antero-superior angle for the simple reason that the brain has not expanded in this part sufficiently to give the stretched-out appearance to the bone which covers it, such as we are familiar with in the modern skull. The same lack of brain development makes itself shown in the Swanscombe skull at the postero-inferior angle, where the line of union between the parietal bone and the mastoid border of the temporal bone, instead of being horizontal or dipping down towards its hinder end, ascends. The brain has not expanded sufficiently to depress the hinder part of the base of the skull to the extent common in modern man. These are features whose significance can easily be overlooked, but, thanks to the beautiful cast of the brain surface, the endocranial cast, it can be shown in explanation of this condition that the parts at the anterior and posterior ends of the fissure of Sylvius (and the whole region of this fissure) show a very primitive stage of development.

Attention has already been called to the foramen magnum, the neck-hole, or the large aperture in the occipital bone through which the spinal cord connects with the brain. We shall do well to consider the foramen magnum of the Swanscombe skull for a moment or two. We all know that in mammals like the cat, dog, horse, etc., the spinal cord enters the skull through a foramen magnum which is at right angles to the floor of the skull, that is, the foramen magnum looks directly backwards.

In the Apes, the foramen magnum looks not directly backwards, but obliquely backwards and downwards; the reason being connected partly with head posture and partly with increase in brain development.

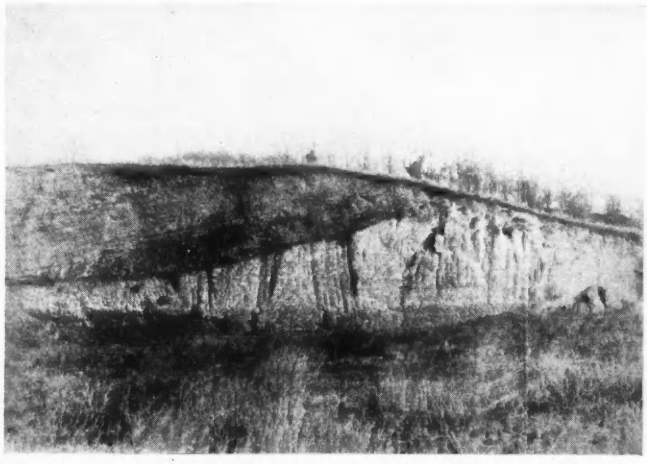
In modern man, where the brain has increased in size out of proportion to that of any other mammal, and where erect posture has been acquired, the foramen magnum looks, not backwards, nor downwards and backwards as in the Apes, but either horizontal or downwards and forwards. This has not been due only to erect posture; principally it has been brought about by the expansion of the frontal and hinder parts, in fact of the brain as a whole, i.e. of the frontal, parietal, occipital and temporal regions of the brain.

Now, in the case of Swanscombe, the two regions of the brain cast which we are enabled to study, the occipital and left parietal regions, both show a low and primitive developmental stage. We know, therefore, that the remaining regions of the brain must have shown the same primitive stage. We must, therefore, expect a low frontal development.

Low frontal, low parietal, and low occipital development means that the base of the skull could not have been bent downwards either at the anterior end or at the posterior end to the extent in modern man. In short it means that in Swanscombe the foramen magnum looked downwards and backwards; not backwards to the extent shown in the Ape skull, but nevertheless somewhat backwards. While it is not suggested that Swanscombe Man was a missing link between Man and Ape, or even that Man evolved directly from the

Anthropoid Apes, it should be remembered that Apes and Man had at some time in the remote past an ancestor common to both, and primitive man can be expected to have retained some of his early simian inheritance.

By this consideration of head balance we are therefore permitted, in the Swanscombe, as in the Neanderthals, to visualize a type of man with the head set forward, and with the massive type of lower jaw already known to us in Heidelberg and Pekin Man, neither of which are Ape-like in respect to the teeth. If our future work is attended with success, it is confidently expected that the missing parts of the Swanscombe skull, the face and the jaws, will justify the term "pre-Neanderthal hominid" for this type of man, rather than justify the insistence of the application of the label *homo sapiens*. Culturally, the Neanderthals were more advanced than Swanscombe. Just as a clever craftsman can make a small blade of a penknife serve his will, the Neanderthal race were able to prepare from one block of flint far more implements than was the wont of Acheulean Man.



The west bank of the Barnfield River resting on the slope of the Thanet Sand. Note the dipping down of the beds of gravel

The Size of the Brain

As to the size of the brain, if one attempts to apply to this archaic specimen the formulae used for calculating the brain capacities of modern specimens, such as Hooke's formula, one asks for error. I have made a considered restoration of the endocranial cast, in order to reproduce the frontal and temporal regions in keeping with the developmental stage of the known occipital and left parietal regions. This cast when measured by immersion in millet seed, a convenient method of direct measurement and more dependable than the use of formulae, gives a cranial capacity of less than 1100 c.c., but it should be borne in mind that, since the specimen is incomplete, the restoration is theoretical.

What do we know about the life of Acheulean Man? We know him by his handiwork. There was nothing of the Ape about it. He fashioned, out of blocks of flint, implements which for their symmetry and sense of proportion exhibit an assiduity and control of material which many moderns who try to emulate his example find difficult to achieve. These implements are less likely to have been weapons of offence against his fellows than to have been used in the hunting of the animals whose bones are found in the same deposits. It is apparent from the large hollow scrapers which are sometimes found, and which suggest they may have been used for rounding off shafts of wood, that he used wood-pointed spears for hunting. The abundance of implements in one locality suggests tribal conditions. He lived at this time in open stations, on the banks of

rivers or on sandy stretches. The existing animals, the warmth-loving elephant and rhinoceros, etc., suggest a warm African-Asiatic type of climate, and it is probable that he was nude, and that he was dark-skinned. Nothing is known about burial customs, although the point has been raised as to whether these early Stone Age men practised cannibalism. In those instances where cannibalism has been conjectured, as, according to Dr Weidenreich, may have been the case with Pekin Man, the base of the skull has been missing; the view has been put forward that this was not merely due to the disintegration of the bones, but to a purposeful fracture after death in order that the brains could be extracted for eating.

However likely or unlikely that hypothesis might be, in the case of the Swanscombe skull the foramen magnum was not destroyed. There are, however, two interesting pits on the parietal bone which were not caused after death, but which may have been due to injury received during life, perhaps by a fall, perhaps by a missile which hit the wrong mark. But if one considers cannibalism solely in the light of its being a rite, one might quite well be permitted to doubt whether man of a quarter of a million years ago had already evolved the religious sense sufficient to call into being the need for the propitiation of the departed spirit, or the wish to identify his own personality with that of the departed, and to acquire, by the act of eating his flesh, the virtues and good qualities of the departed person.

If cannibalism were not practised as a rite, the abundance of animal food evidenced by the frequent animal remains at Swanscombe points to the fact that Swanscombe Man had plenty of food at his disposal in the form of deer, elephant, rhinoceros, bison, etc., to supply his physical needs without coveting his neighbour's body.

Extremely large pointed flints, crudely made and of a weight surpassing anything that would ordinarily be used as a hand weapon, suggests that these were used as pointed dropping tools suspended over pits or water holes which, in dropping, would transfix the animals. Such implements have been found embedded in a mud silt which, from their concentration, would appear to have been a water hole, immediately over a collection in the same cubic yard of bones of elephant, rhinoceros and deer.

Actual working floors have been found on which the flakes struck off from a flint in the manufacture of implements tell us something of the actual technique practised.

Swanscombe Man was man on the ladder of evolution. Despite the hard conditions of such a life, his implements tell us that he succeeded in making even the stones on which he trod become a perpetual monument to his skill, and the recent happenings in this twentieth century of the Christian era may make some of us wish that we could again enjoy the simplicity of the 250th millennium before that era.

Colour in Painting

By Mary Barne

I. The Importance of Colour in Art: Definitions

"*Le premier mérite d'un tableau est d'être une fête pour l'œil. Ce n'est pas à dire qu'il n'y faut pas de la raison: c'est comme les beaux vers, toute la raison du monde ne les empêche pas d'être mauvais, s'ils choquent l'oreille. On dit:* 'avoir de l'oreille'; *tous les yeux ne sont pas propres à goûter les délicatesses de la peinture. Beaucoup ont l'œil faux ou inerte; ils voient littéralement les objets, mais l'exquis, non.*"

Last entry in Delacroix's Journal.

Though painting in oils has been in my mind all through while writing these articles, I have never used the word Colour as a synonym for paint (as is the custom), but always in the sense of colour in the abstract. I have discussed technique as little as possible, as the series is intended more for the picture-lover than for the painter.

Almost all the works I have mentioned are in well-known and easily accessible London galleries.

It has been the fashion, during much of the present century, to look upon colour as one of the less important factors in picture making. This is, no doubt, due to the widespread interest in photography and in the cinema; these must tend to make the visual imagery monochromatic. It is true that coloured photography and colour films are slowly gaining ground; but they excite little enthusiasm as yet, and, indeed, will have to improve greatly before they can arouse much aesthetic emotion. Meanwhile, many thousands of folk go to stare at the "pictures", quite content with their (literally) colourless evenings. In music, the exact analogy to this would be to listen to a long concert of "percussion music", or (since the interest taken is, to so great an extent, in the subject-matter) to hear a lengthy tale "intoned" in monotone.

Of course, just as "percussion music" played in correct time and correct "dynamics" (loud- and soft-ness) is better than wrong notes, so monochrome is better than bad colour.

Colour is, beyond all doubt, one of the most important elements of Design. This importance shows itself in three ways:

A. As decoration. I need not speak of the intense sensuous enjoyment—to colour-lovers the most intense of all pleasures of the senses, and free from any taint of grossness—that it can give. "We have", writes Professor Alexander, "received yet one more gift, something not quite necessary, a benediction as it were, in our sense for enjoyment of colour." This decorative value is, just now, becoming more fully appreciated, and there is a movement back to "positive colour"—apparent chiefly in house decoration, both in and outside. But this movement is uninstructed, largely to the practice in many schools of teaching Ostwald's crude notions of harmony, etc.

B. Although, as Roger Fry wrote truly, "The emotional effect of colour is neither so deep nor so clearly determined as that of the other elements of design", yet it has fairly definite emotional and psychological effects—mostly the result of association. But shapes (especially proportion in architecture) and, above all, tone (chiaroscuro or light-and-shade) appeal more strongly to the emotions.

C. Colour has great formal or "constructive" value in design. Goethe wrote: "All Nature manifests itself by means of colours to the sense of sight." Leonardo da

Vinci expressed the same idea in his *Treatise on Painting*: "The end of one colour is only the beginning of another." That is to say that, to the normal eye, the shapes of things (or where one leaves off and another begins) are distinguished quite as much by differences of hue, as of tone. It is true that the tones from black to white, or differences in luminosity—what the painter calls "values"—are immense, if not infinite, in number; but many of them are colour values, with which I will deal later. One more quotation, while on this subject—an eloquent passage from Mr Adrian Stokes's *Colour and Form*: "The colour of Venetian painting is fine not because it expresses a fine sensuousness but because it expresses a noble apprehension of the forms of the outside world."

It is often said that colour, in art, is unimportant owing to the fact that many male infants are born with some form—always incurable—of colour-blindness (these defects are extremely rare among women). But the percentage is not high—Sir John Parsons, in his *Colour Vision*, puts it at about 4 %.

It would seem quite as reasonable to call the difference in pitch between one musical note and another unimportant, for exactly the same sort of reason; for I should imagine the percentage of people with defective "musical ear" to be much higher, considering that this failing is (I believe) as common in one sex as in the other.

Complete achromatism—black-and-white vision—is, according to Sir John Parsons, extremely rare, and it is always accompanied by other grave visual defects.

On no subject with which I am acquainted is there such confusion of nomenclature—and of thought—as on this one of Colour. Some theories include black among the colours; though blackness, the result of total absorption (and therefore non-reflection) of light, is the very negation of colour. One might as well call silence a sound.

As everyone knows, a beam of white light can—by being made to enter a different medium from air (such as glass)—be, as it were, split into a series of hues which, owing to their graduated differences of wave-lengths, and therefore of refraction, appear always in the same order—whether in the solar or any other spectrum, or in the rainbow, or in soap bubbles.

Waves of air must be *regular* before any musical note—even the monotone of a drum—is formed. And the electro-magnetic stresses and strains, that are the cause of light of visible wave-length, must produce regular vibrations before any *positive* colour (i.e. not white or grey) can be seen. Light waves spread out spherically, and every object on which they fall has the power of either

(1) reflecting all the rays, thus appearing white,

(2) letting them pass through; it is then transparent,

(3) absorbing them all, and appearing black,

(4) regularizing them—i.e. separating them into bundles of waves—the waves in each bundle are of one length only. Some of these bundles the object absorbs, but one or more it reflects. Those reflected give the object its colour.

Pigments are impure in colour, i.e. they each reflect several "light bundles" or, in other words, light from several parts of the spectrum.

For the sake of clearness, I give a few definitions. A coloured surface can vary—*as to colour*—in three ways only:

(1) Hue, which depends on wave-length.

(2) Luminosity, or intensity of light (a measurable quantity), which depends on the wave's amplitude. This quality of luminosity, in painting, might be described as that which is altered by adding black to a pigment.

(3) Saturation, or strength (sometimes called—not quite accurately—depth of colour), which depends on admixture of, or freedom from, white light.

Thus, corresponding to these three variables, we get, respectively, different *hues*, *shades*, and *tints*. These terms I shall use, very strictly, in the senses corresponding respectively to the three above-named "dimensions" of colour, and in no other.

It is by the innumerable combinations and permutations of these three methods of appearance that we see the visible world in all its complexity.

I shall, throughout, use the (plural) term "chromata" for the hues of the solar spectrum, popularly supposed to be seven, but of which hundreds of gradations can be distinguished by persons of exceptionally good eyesight.* This is shorter and simpler than either of the terms "spectral hue" or "positive hue". Under this name I also include the non-spectral blends of red and blue (the purples and magentas). All the other non-spectral hues: white, the greys, browns, olives, etc.—formed by mixtures of more than two chromata—I will call, simply, colours. By the term "chroma" will be meant the quality of appearing in any spectrum or of being a blend of two of its end-colours.

WHAT IS "GOOD COLOUR"?

The Oriental love of fine colour is proverbial. For many centuries the Chinese in their paintings on silk, the Moors and Persians in their textiles, ceramics, etc. (the Persians above all in their carpets), and for some two hundred years the Japanese in their colour prints, have shown a refined taste, and an unerring skill in combining bright strong chromata which would, in European hands, in our Dark and Middle Ages—when Eastern art was at its height—have probably led to garishness and discordance. Their colour—in other words—was unfailingly "good". The Venetian, the Dutch, and the Spanish schools of painting most likely acquired their mastery over colour by intercourse with the East—the Venetians and Dutch through trade with the Levant and East Indies respectively, the Spaniards through the Moorish invasion.

In Europe, things are rather different. As he goes round a picture gallery, a person with an eye "for the exquisite" in colour, experiences many pleasures—but also many pains. Let such a person visit our National Gallery; he will wander somewhat disconsolately through the early Florentine, Sienese and Umbrian rooms, hung with acres of pink-faced Madonnas clad in harsh blues and reds—though the "toning down" of the pigment colours by the gold backgrounds may please him. He might think that an exhibition of heraldry, with its bright *or* and *argent*, glowing *gules*, and soft *azur* would be preferable, since no pink would spoil the harmony. He would pause before Uccello's "Rout of S. Romano", for that is a piece of fine heraldic blazon, pure and simple; and before the da Forlis, and Piero della Francescas—good colour here—deep and satisfying in the former, delicate as a butterfly's wing in the latter. The Florentine Renaissance paintings would seem far less crude than the "Primitives"; he would note Piero di Cosimo's rich and harmonious colouring; and, in Perugino's work, a beginning of atmospheric effect. In some of the Raphaels, he would see Perugino's softness carried to excess—without the atmosphere, though he could not but admire the pearly luminosity obtained by this master through his system of glazing. He will, at present, also pass through the Samuelson and Gulbenkian Loan Collections. In the former, he will note the change from the hardness and superficiality of the colour of the "Golden Calf" by an early Florentine (I think one of the Lippis) to the fine colour of "St Ursula leaving her father" by Carpaccio—a Venetian of the same date.

But it is when our colourist reaches the Venetian rooms that the real enchantment will begin. The Bellinis (especially perhaps Gentile, whose "Madonna and Child enthroned" in the Mond Collection should

* The late Lord Rayleigh wrote that he could distinguish 1000 in a good spectrum.

not be missed), Cima, Bassano, Basaiti, Moretto, Savoldo in his "S. Jerome" with the glorious blues of its distances (Savoldo and Moretto were Brescians, but in colour they often equalled the Venetians). Then Giorgione—poorly as he is represented here—and his follower Bonifazio. Above all, Titian. All these men's works show us, to a more or less degree, colour at its greatest.

National Gallery

Manet's "Boy With Cherries"

In the later Venetian rooms we see the gorgeous paintings of Veronese, who, however, with all his virtuosity and all his sumptuousness, has lost something of the perfection of the earlier men. For (I would drive home this point all through) good colour has no connexion with any great quantity of chroma or variety of hue, but with such things as the richness and glow and depth, and harmony, of what chroma is there. These qualities would delight our colourist in the works of Canaletto and Guardi, Longhi (especially the portrait by him in the Mond room), and, more than all these, in Tiepolo's paintings, for his colour is exquisite.

This sense of pleasure would continue as our observer passed on to the Dutch rooms; he would note especially the delicate yellows and cool blues of Vermeer, the glowing reds of de Hooch, and the jewel-like touches of gleaming chroma with which Rembrandt relieves his sombre schemes.

In the Spanish room he would be surprised by the restraint, as to colour, shown by men from a country where the very rocks are brilliantly chromatic. But the colour is there. Velazquez's works are full of it —though not of chroma; against a background of softest green-grey he builds up his picture with rich browns and mysterious blacks—then lets himself go with a touch of vivid blue or crimson. And observe the fine deep quality of the red in Zurbarán's "Lady as St Margaret" and the delicate tints of Coello's "Betrothal". Like Zurbarán, Murillo has a sudden glow of red amid sombreness—best seen in his "St John the Baptist" in the Mond Collection. What a contrast to the Flemings (in the two rooms next the Spaniards), to say nothing of the Germans on the other side. Here there is clarity—and a "shine" such as one sees on Academy pictures—but how hard—what discordant chromata!

In the French rooms we find the Claudes, Nicolas Poussin's beautiful "Phocion"

landscape (the only Poussin here with good colour), the Chardins, and a Delacroix. In all these, not much chroma, but what they *have* is magnificent in quality. And one Watteau—his colour seems to me to derive straight from the Venetians, though, unfortunately, it has faded as theirs has not.

Lastly, in the larger French room, come a few examples of "Impressionism" (a misleading name for the work of men whose methods were the very reverse of slapdash or hit-and-miss). To look at their paintings after the others is like coming out of a dark room into a sunlit garden; there are broad patches of bright chroma, but the effect is not gaudy, for these patches are "broken" with skilful touches that often give shimmering effects, as of air that quivers with heat. Manet's colour is more beautiful, perhaps, than that of any other modern painter—look at the glowing red in the "Boy with cherries", and the soft blue in the "Soldier trying the lock of his rifle" and note the harmony of colouring in the "Bar des Folies-Bergère". But he was nearly as restrained in his use of chroma as was the object of his veneration and lifelong study: Velazquez. The only member of the group who disdained all sobriety in the use of colour was Renoir (and who can regret it when looking at his flower paintings, at any rate?).

What chiefly characterized the Impressionists' work, from the colourist's point of view, is the close observation of the fact that chroma, varying in tone and in quality, exists almost everywhere in Nature, lurking even in shadow. For shadows are always coloured, and often chromatic—inclined to be complementary to the lightest portion of the surface on which they fall; this effect is partly subjective, the result of simultaneous contrast.

Now we come to the British rooms. I think we may say that our own country's principal painters have all excelled in colour. A few of them, indeed—Gainsborough, Richard Wilson, Turner, Constable—and Rossetti in one picture at least—are among the world's greatest colourists. (Rossetti's masterpiece is here: the little "Ecce Ancilla Domini!", apparently so simple, yet in reality how subtle in its play of contrasting whites.)

National Gallery

Rossetti's "Ecce Ancilla Domini!"

Turner's colour sense was often in abeyance, but, in his best period, his colour

had an iridescent beauty not of this world. In such works as "Ulysses deriding Polyphemus" and "Rain, Steam, and Speed"—both in this gallery—he seems to paint, not with pigments, but with the very colours of the spectrum themselves. In his effects of sunlight and atmosphere he anticipated the Impressionists. Whistler, too, has wonderful passages in his "Little White Girl", and "Old Battersea Bridge", to a colour-lover, is perfect. And J. F. Lewis's "Siesta" is a fine harmonious piece of decoration.

Hogarth and Reynolds were very great painters, but not, perhaps, in the first rank of colourists.

What constitutes good colour? Certainly not a great many unrelated chromata on one canvas. Two of the most beautiful pictures in London—as regards colour alone—are Velazquez's "Infante Don Baltasar Carlos as a baby" in the Wallace Collection, and the Rossetti mentioned just now. In the Velazquez, the chromata appear only in the dark-red curtain, purple sash and gold collar-edge; the effect of the child's dress, which occupies most of the picture, is one of delicate silvery colour—but this is obtained by tiny touches of yellow, so the chroma is there too; the yellow in the dress carries on the gold of the collar-edge, but of this one is unconscious unless one looks closely.

In Rossetti's picture, the chromata consist of a slightly greenish (cyan) blue—deep in the curtain, paler in the early-morning sky—the red of the embroidery frame, and the yellows—varying in tone and strength—of the halos, and of Mary's hair, and of the flames at the angel's feet.

On reflection one comes to the conclusion that good colour depends mainly on three constituents, which are connected respectively with the three "variables" mentioned earlier.

These constituents are:

(*a*) Harmony of hues.
(*b*) Balance of tone, or of "colour-values".
(*c*) Good quality of colour.

(*To be continued*)

This is the first of a series of three articles by MISS BARNE on Colour in Painting. *In later issues she will discuss* Colour Harmony, Balance of Tone, *and* Colour Quality. *Her mention of specific works will be taken as excuse enough to reproduce them here, as reminders of the originals, and for their own sake: but to get the full meaning of her arguments reference to the actual paintings is, of course, a great advantage. Most of the pictures referred to are to be found in English galleries.*

National Gallery

Whistler's "Little White Girl"

Mr Tompkins in Wonderland

By Professor G. GAMOW

Dream II: The Quantum Room*

THE second lecture that Mr Tompkins attended was about the problems of quantum theory. It was still less understandable than the first, as the professor spent most of the time trying to persuade his listeners that such simple notions as the position or the velocity of any material object are not simple at all, but are represented by "infinite matrices", which made absolutely no sense to our poor Mr Tompkins. The professor even took the trouble to draw a picture of a matrix which looked something like this:

$$\begin{array}{cccccc} 9_{11} & 9_{12} & 9_{13} & 9_{14} & 9_{15} & \dots \\ 9_{21} & 9_{22} & 9_{23} & 9_{24} & 9_{25} & \dots \\ 9_{31} & 9_{32} & 9_{33} & 9_{34} & 9_{35} & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \end{array}$$

This, however, was not much help to anybody. Neither did most people find much help in the professor's explanation that "matrices do not commute". Only towards the end of the lecture a familiar word struck Mr Tompkins's ear. The word was "uncertainty", which, in some mysterious way, was supposed to follow from the "previous considerations" and "the noncommutability of matrices" (whatever that was). According to the professor one could never be quite certain about the exact position or the velocity of an object. "Well, I am certain anyway where my car is parked", thought Mr Tompkins, leaving the lecture room.

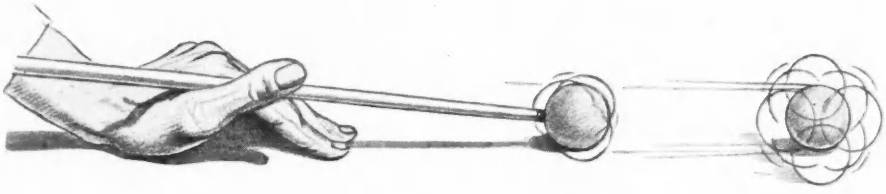
Driving home, he looked occasionally at the speedometer showing exactly 30 miles an hour, which was the city speed limit. "Uncertainty in velocity!" he remembered; "a good thing the police have never heard such stuff—or they would fine me for going 'to a certain extent' above a hundred!" Finally, he was home and in his bed. "Yes, in the bed and *not* in the lecture room, matrices or no mattresses..." thought he, falling asleep.

* * * *

Unexpectedly, he found himself in a big smoking room with several people in shirtsleeves playing billiards on the central table. He vaguely remembered being here before, when one of his fellow clerks took him along to teach him billiards. He approached the table and started to watch the game. Something very queer about it! A player put a ball on the table and hit it with the cue. Watching the

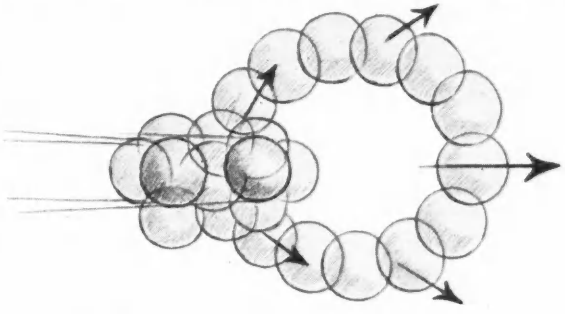
* In this story the quantum-constant h pertaining to the motion of the billiard-balls is equal to 1 erg/sec.

rolling ball, Mr Tompkins noticed to his great surprise that the ball began to "spread out". This was the only expression he could find for the strange behaviour of the ball which, moving across the green field, seemed to become more and more washed out, losing its sharp contours. It looked as if not one ball was rolling across the table but a great number of balls, all partially penetrating into each other. Mr Tompkins had often observed analogous phenomena before, but to-day



he had not taken a single drop of whisky and he could not understand why it was happening now. "Well," he thought, "let us see how this gruel of a ball is going to hit another one."

The player who hit the ball was evidently an expert and the rolling ball hit another one head-on just as it was meant to. There was a loud sound of impact and both the resting and the incident balls (Mr Tompkins could not positively say which was which) rushed "in all different directions". Yes, it was very strange; there were no longer two balls looking only somewhat gruelly, but instead it seemed that innumerable balls, all of them *very* vague and gruelly, were rushing about within an angle of 180° round the direction of the original impact. It resembled rather a peculiar wave spreading from the point of collision.



Mr Tompkins noticed, however, that there was a maximum flow of balls in the direction of the original impact.

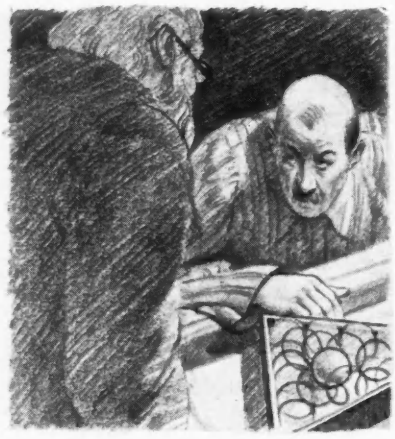
"Scattering of S-wave", said a familiar voice behind him and Mr Tompkins recognized the professor. "Now", exclaimed Mr Tompkins, "is there something curved again here? The table seems to me perfectly flat."

"That is quite correct", answered the professor; "space here is quite flat and what you observe is actually a quantum mechanical phenomenon."

"Oh, the matrix!" ventured Mr Tompkins sarcastically.

"Or, rather, the uncertainty of motion", said the professor. "The owner of the billiard room has collected here several objects which suffer, if I may so express

myself, from 'quantum-elephantism'. Actually all bodies in nature are subject to quantum laws, but the so-called quantum constant which governs these phenomena is very, very small; in fact, its numerical value has twenty-seven zeros after the decimal point. For these balls here, however, this constant is much larger—about unity—and you may easily see with your own eyes phenomena which science succeeded in discovering only by using very sensitive and sophisticated methods of observation." Here the professor became thoughtful for a moment.



"I do not mean to criticize," he continued, "but I *would* like to know where the man got these balls from. Strictly speaking, they could not exist in our world, as, for all bodies in our world, the quantum constant has the same small value."

"May be he imported them from some other world", proposed Mr Tompkins; but the professor was not satisfied and remained suspicious. "You have noticed", he continued, "that the balls 'spread out'. This means that their position on the table is not quite definite. You cannot actually indicate the position of a ball exactly, the best you can say is that the ball is 'mostly here' and 'partially somewhere else'."

"This is very unusual", murmured Mr Tompkins.

"On the contrary," insisted the professor, "it is absolutely usual, in the sense that it is always happening to any material body. Only, owing to the small value of the quantum constant and to the roughness of the ordinary methods of observation, people do not notice this indeterminacy. They arrive at the erroneous conclusion that position or velocity are always definite quantities. Actually both are always indefinite to some extent, and the better one is defined the more the other is spread out. The quantum constant just governs the relation between these two uncertainties. Look here, I am going to put definite limits on the position of this ball by putting it inside a wooden triangle."

As soon as the ball was placed in the enclosure the whole inside of the triangle became filled up with the glittering of ivory.

"You see!" said the professor, "I defined the position of the ball to the extent of the dimensions of the triangle, i.e. several inches. This results in considerable uncertainty in the velocity, and the ball is moving rapidly inside the boundary."

"Can't you stop it?" asked Mr Tompkins.

"No—it is physically impossible. Any body in an enclosed space possesses a certain motion—we physicists call it zero-point motion. Such as, for example, the motion of electrons in any atom."

"Does my car also move when it is locked in the garage?" asked Mr Tompkins.

"Yes, of course. And if it were made of the same unbelievable stuff as those billiard balls it would not stay long in the locked garage."

"You mean it would break the doors and run away?" asked Mr Tompkins in great surprise.

"A ridiculous suggestion!" said the professor. "It would not break the doors—it would just leak out through the doors like a good old ghost of the middle ages."

Mr Tompkins looked suspiciously at the professor. "Now I have caught him", he thought, and continued: "Well, luckily enough my car is not made from the same elephantine ivory as these balls—it is made from ordinary steel. But didn't you say that all materials are subject to quantum laws, though the constant is very small? How long have I to wait until my car *does* 'leak out' from the garage? I would like to see it and to check what you have just said!"

After making some rapid calculations in his head, the professor was ready with the answer: "It will take about 1,000,000,000.....000,000 years."

Even though he was accustomed to large numbers in the bank accounts, Mr Tompkins lost the number of noughts mentioned by the professor—it was, however, long enough for him not to worry about his car running away.

"Suppose I believe all you say. I cannot see, however, how such things could be observed—provided we do not have these balls here."

"A reasonable objection", said the professor. "Of course I do not mean that the quantum phenomena could be observed with such big bodies as those with which

you are usually dealing. But the point is that the effects of the quantum laws become much more noticeable in their application to very small masses such as atoms or electrons. For these particles, the quantum effects are so large that ordinary mechanics become quite inapplicable. The collision between two atoms looks exactly like the collision between two balls which you have just observed, and the motion of electrons within an atom resembles very closely the 'zero-point motion' of the billiard ball I put inside the wooden triangle."

"And do the atoms run out of the garage very often?" asked Mr Tompkins.

"Oh yes, they do. You have heard, of course, about radioactive bodies, the atoms of which spontaneously disintegrate, emitting very fast particles. Such an atom, or rather its central part called the atomic nucleus, is quite analogous to a garage in which the cars, i.e. other particles, are stored. And they do escape by leaking through the walls of this nucleus—sometimes they will not stay inside for a second. In these nuclei, the quantum phenomena become quite usual!"

Mr Tompkins felt very tired after this long conversation and was looking round distractedly. His attention was drawn to a large grandfather clock standing in the corner of the room. The long old-fashioned pendulum was slowly swinging to and fro.

"I see you are interested in this clock", said the professor. "This is also a mechanism which is not quite usual—but at present it is out of date. The clock just represents the way people used first to think about quantum phenomena. Its pendulum is arranged in such a way that its amplitude can increase only by finite steps. Now, however, all watchmakers prefer to use the patent spreading-out-pendulums."

Mr Tompkins, in rather a worried state of mind, was intently watching the grandfather clock with a certain funny-looking formula written on it. Presently the pendulum began to spread out, and soon its shadowy forms seemed to occupy all the room. The surrounding objects and the professor himself became vaguer and vaguer as they gave place to the more familiar contours of his bedroom. He was waking up....

Notes of the Month

PROFESSOR G. Gamow, author of *Mr Tompkins in Wonderland*, is one of the younger generation of Soviet scientists and now Professor of Theoretical Physics at George Washington University. He is known throughout the scientific world for his original work on the theory of atomic nuclei. He is also known for having included, among his profound scientific contributions, specimens of an odd and characteristic humour; it is not very often one meets jokes in the middle of a scientific paper.

Mr Tompkins in Wonderland combines Professor Gamow's deep knowledge of modern physics with his particular brand of humour. It is an attempt to make clear to the man-in-the-street the new theories of space and time. The first dream, *Toy Universe*, appeared in the December number of *Discovery*.

Sir Richard Gregory

The visit of Sir Richard Gregory to the United States to lecture on the promotion of the social and international relationship between England and America coincides with his retirement from the editorship of *Nature*, the journal with which he has been associated for forty-five years.

At the recent annual meeting of the British Association at Cambridge, delegates from the American Association for the Advancement of Science were present, to promote co-operation of the main interests of the two organizations, with particular regard to social and international relationships. It was resolved at that meeting to establish a new Division of the British Association for the study of the Social Relations of Science, and Sir Richard Gregory has since been appointed chairman of the Division.

In recent years these repercussions of science on society, and the social problems arising from the impact of science on modern life, have been given much attention in this country as well as in France and America, and they represent a strong movement towards the formation of one group in a world community. Sir Richard Gregory has accepted invitations to lecture on the subject at several universities while he is in the United States. On 8 December he delivered a lecture on "Cultural Contacts of Science" at the new auditorium of the Carnegie Institution, Washington.

Transfusion of Stored Blood

In Moscow, 23 March 1930, a young engineer tried to kill himself by cutting the arteries of his elbow. He was rushed to the Sklifassovsky Institute, Moscow's big first-aid hospital, and brought in nearly dead from shock and loss of blood. An

ordinary serum injection failed and no blood donor was available for transfusion. Dr Serge Yudin then made an unprecedented transfusion. Six hours before, an old man had been brought in dead with a fractured skull. His blood was removed and nearly three-quarters of a pint, suitably treated, was injected into the young man. Two days later the would-be suicide left the hospital cured and well. He was the first of a series of hundreds of men alive to-day because one scientist took a risk and faced certain prejudices.

When Dr Yudin performed this transfusion, the process had over two years of experimental backing. In 1928 Professor Shamov had read a paper describing the transfusion of blood from dead dogs to barely living ones, dying from severe haemorrhage. The dogs had recovered.

Since then Dr Yudin had considered the idea of repeating this on human beings. Daily in his hospital he experienced the difficulties of ordinary blood transfusion. Every night three or four cases would come in needing blood. The blood-donor service was insufficient to cope with this. Professor Shamov's experiments had suggested the solution. From a dead body one can remove more than three times the blood a live donor can spare, and in an accident hospital dead bodies are unfortunately only too common.

To justify such a transfusion Dr Yudin waited for a case whose death was otherwise certain. That the engineer himself had tried to take his own life was another factor lessening the surgeon's responsibility.

Dr Yudin repeated his first success with six more cases. Then with the official approval of the Ukrainian Surgical Society his work forged ahead. Two years later he had worked on 130 cases, "...without ever having found in any way that the blood from a dead body gave inferior results than the blood of living donors". And by now well over a thousand cases have been treated in this fashion. Of these only five failed to recover. The technique is now so perfected that it is no longer reserved for emergency cases; the Russian doctor uses it for the routine treatment of all sorts of conditions which need blood.

Age makes no difference. The blood from a young man killed in an accident is just as good as that of an old woman dead of heart failure. But various difficulties remain. The blood must be taken within eight hours of death if it is to remain quite liquid, uninfected, and non-poisonous. It must be thoroughly tested before it can be used. Human beings are grouped into four different blood types; mixture of different blood groups causes clotting in the body and is generally fatal. A patient with group IV blood, for instance, cannot receive the blood of groups I, II or III, but must have his own group. Before any transfusion is performed the groupings of the two bloods must be carefully checked. This, of course, is true of transfusions from a living donor. The donor will have to be proved free from important infectious diseases. These tests take time and are essential; yet time is the one thing that cannot be afforded in emergency cases.

The next important step was that instead of using blood directly from the body,

Dr Yudin found a method of storing it. He could keep reserves in his hospital, reserves already grouped and tested, ready for instant use. Treated with a chemical to prevent clotting and kept at a low temperature, the blood remains good and fluid for periods as long as four weeks.

In Great Britain the method is not likely to be used for some time. For this country has an extraordinary efficient blood transfusion service and can rely on living donors. That, however, is no reason to overlook a new scientific advance in emergency treatment, a method to save lives, with (as one medical man put it) "...the co-operation of patients who have passed beyond the reach of help for themselves".

(*From A. S. Playfair*)

The Transformations of Energy and the Mechanical Work of Muscles

The heat given out by muscles in relation to the work done by them is one of the classical studies of physiology. Until recently, however, the matter appeared much more complicated than it really is, owing to technical difficulties. These have been overcome by the use of a very rapid recording system and an insulated thermopile only 0·002 in. thick. The success achieved represents one of Professor A. V. Hill's experimental triumphs.

Some very simple relationships have now emerged. An active muscle liberates energy in three forms: in maintaining a contraction, as heat; in shortening, as heat; in shortening against load, as work; its behaviour in any circumstances is deduced from the resultant of these three. *Rate* of total energy liberation of a muscle is determined by the load upon it, increasing as the load decreases. This allows a simple equation to be deduced for the relation between speed and load. The constants of the equation are the same whether they are obtained by thermal or by mechanical measurements. This is strong confirmation of the results and of the conclusions based on them.

The fact that a muscle does less external work when shortening at a higher speed has led to the hypothesis that muscle is endowed with "viscosity". This viscosity has been attributed to a lag in the rearrangement of its molecules, as the external form of the contractile elements changes. It is now shown that this viscosity hypothesis is altogether unnecessary, and that the decrease of force and work with increased speed can be deduced from the manner in which the energy liberation is regulated.

Some applications are described. The maximum power developed by a muscle is with a load about three-tenths of the maximum load it can bear. The highest efficiency (work/total energy) is with a load of about 0·45 of the maximum. These are near enough for maximum power and maximum efficiency to occur very nearly at about 37 % of the maximum load. These results obtained with frog's

muscle almost certainly apply, though possibly with different constants, to man, and it would be necessary to find out and to determine the constants of human muscle. The technique required, however, would be very different.

A Report on Agricultural Research

Every year the world's farmers suffer huge losses from animal and plant diseases, from crop failures, from use of unsuitable breeds or strains and from mistakes in management and marketing. More than half the families on earth belong to farmers, and the total effect of all these losses is staggering. It means dearer food, low farm incomes and restricted trade. The task of finding out how to reduce the waste falls upon a handful of agricultural research workers, largely in Britain. There are nearly a thousand men and women engaged in adding to knowledge in this way in twenty-eight research institutes and many other institutions. Although the taxpayer finds £700,000 a year for this work, he takes very little interest in it. Few people realize the rapidity of the advances, for which research is largely responsible. The average British farm worker to-day raises just about three tons of saleable foodstuffs, where as lately as 1924 he produced only two.

Even farmers are often unaware of facts which might be extremely useful to them. For instance, it is estimated that a million tons of potatoes are lost annually in Great Britain through virus infection which could be avoided by the use of suitable stocks.

Research institutes have grown up haphazard, and some of their work has been wasted because not nearly enough has been done to inform the farmer about new methods. Too much of this task has been left to the county councils, many of which have not the funds or staff to do it properly, while useful instruments like films have been neglected. The Ministry of Agriculture has actually only twenty films in stock, some being fourteen years old, while the U.S. Department of Agriculture has 231 films available on loan.

These facts are taken from a *Report on Agricultural Research in Great Britain*, issued by the group called PEP (Political and Economic Planning), 16 Queen Anne's Gate, London, S.W. 1. This *Report* will shortly be reviewed in *Discovery*. The *Report* criticizes the inadequate means of making information available to farmers and the public, the low pay and poor prospects of agricultural research workers as compared with other scientists, and the unduly complicated administrative and financial arrangements. Its main proposals are:

(*a*) The creation of more husbandry institutes, dealing with everything relating to a particular crop or product rather than with a particular branch of science.

(*b*) The placing of the county advisory service under the provincial advisory centres, instead of as at present under the county councils.

(*c*) Establishment of a Central Extension Service for putting over research results.

(*d*) Improvement of staff conditions.

(*e*) Creation of a Central Agricultural Research Fund with larger contributions from the industry.

(*f*) Elimination of the Development Commission, and simplification of control of agricultural research under the Agricultural Research Council.

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In last month's issue we published an article on "Some Problems of Modern Street Lighting". The illustrations on page 456 were reproduced by kind permission of the D. Appleton Century Co. Inc. from the book *Artificial Light*, by M. Luckeish.

* * *

Rudolphi, Braunlage

Snow in the Harz, Germany

A New Tool in Biology

By Dr C. H. WADDINGTON

FEW people who read about the extraordinary success of modern physics in understanding the detailed structure of chemical atoms are likely to realize that this knowledge is almost certainly going to revolutionize our ideas about food and living processes in general. Actually, recent developments in physics have just provided biologists with a new tool, which, one can see already, is going to be an extremely powerful instrument of analysis.

The most difficult of all biological phenomena to analyse is normal health. In order to make an experiment, we nearly always have to do something abnormal to the animal, and that animal is in consequence to some extent in an unusual state. In investigating the digestion, absorption and utilization of food, for instance, we have two courses open. We can give the animal some peculiar substance in its food, and determine how the body deals with it. Or alternatively, we can give normal food, but then the amount of information we can get about its fate in the body is very limited. The animal already contains a large quantity of the products of its normal foodstuffs, and we cannot, or could not, distinguish the particular meal given in the experiment from the previous meals. We may, for instance, give some normal protein, which on digestion is broken down to amino-acids, some of which may be built up again into proteins which are laid down in the body and cause it to grow, while some may be broken down still farther and excreted in the urine. But if we find new proteins being laid down after a meal, we cannot be sure whether they have been formed directly from the proteins of the meal or from the amino-acids which the body already contained. And it is extremely difficult to discover for certain which substances can be converted into one another.

The new physics has provided a method of labelling food materials which looks as though it will make it comparatively easy to solve all these problems. The method of labelling is based on the fact that the chemical properties of an atom are determined by its outermost shell of electrons, while its weight depends on the nucleus which lies in the centre of the atom and has little effect on any of its normal reactions. Now a particular element, hydrogen, for instance, is usually a mixture of atoms, all of which have the same outer electrons and therefore the same chemical properties, but which have nuclei of different weights; the different sorts of atoms are known as isotopes. It is possible, by very careful manipulation, to concentrate one particular isotope, so that we obtain a preparation of the element with an abnormal isotope concentration. From this we can make up a food substance, which will also have an abnormal isotope concentration. An animal treats this as a perfectly normal food; and indeed it is perfectly normal in respect of all its chemical properties. The substance therefore undergoes all reactions characteristic of normal life. In order to discover what these reactions are, all we have to do is to investigate all the

substances in the body and discover in which of them there is an abnormal concentration of isotope. This is, of course, not at all easy; it requires very high chemical skill in the isolation of pure substances from the body, and it also requires a very refined physical technique. But given the skill, a method exists by which an only very slightly abnormal concentration of isotope can be detected in a very minute sample. In principle, the method is to break down the substance being investigated into its constituent atoms, and to shoot those atoms through a magnetic field which causes them to travel along a curved instead of a straight path; the extent to which an atom deviates from the straight line depends on its weight, and thus the different isotopes can be distinguished.

As yet this method of labelling foods is in its infancy. There are comparatively few elements in which the isotopes have been concentrated. From the biological point of view, the most important which has been used so far is hydrogen; and nitrogen is just being brought into use and will probably prove very important in the study of protein metabolism. The preparations containing high concentrations of heavy hydrogen have been used mainly for studies on the changes occurring in fats and fatty acids. In some respects the results merely confirmed previous hypotheses; for instance, it was possible to prove conclusively that unsaturated fatty acids can be converted in the body into saturated ones, and vice versa, and that the number of carbon atoms in the molecule of a fatty acid can be reduced by two. But the most interesting fact which emerged from these studies was that the fats in the body are continually changing. If one keeps the weight of a mouse constant by supplying it with just the right amount of food, one might expect that its fat deposits would remain untouched, while the food it is assimilating is used as fuel for the bodily machine. But this is not so. Even at constant body weight, there is a rapid fat turnover, some of the fatty acids being laid down in the fat deposits, while some of the carbohydrates of the food are also converted into fatty acids which are deposited; and one must assume that this deposition is just balanced by fatty acids being liberated from the fat stores to be used as fuel. These changes could hardly have been discovered in any other way; probably the isotope method, when it has been more widely used, will provide many more surprises for us. At least it is clear that it is going to be one of the most important tools of biochemistry.

With this (January) issue *Discovery* enters upon Volume II of the new series. Readers who intend to have Volume I bound, and would like to receive binding title and index are asked to send a card bearing their name and address to

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Is there Life in Other Worlds?

By Dr H. Spencer Jones, F.R.S.
(*Astronomer Royal*)

One of the results that has followed from the employment in astronomy of larger and larger telescopes is a clearer recognition of the vastness of the universe. We see our Sun as an average sort of star, eccentrically situated in a disk-shaped stellar system containing something like one hundred thousand million stars and of such great extent that light takes more than one hundred thousand years to travel from one end of it to the other. The depths of space are peopled by myriads more of such systems, not differing greatly in size and general structure, at an average distance apart of the order of one million light-years. With long exposures on fast plates under good conditions, the 100-inch telescope can just reveal such systems at a distance of five hundred million light-years. Within a sphere of this radius there are about one hundred million systems, yet there is no indication of any thinning out in the distribution at the extreme limit to which the largest telescope can reach.

Is the Earth unique?

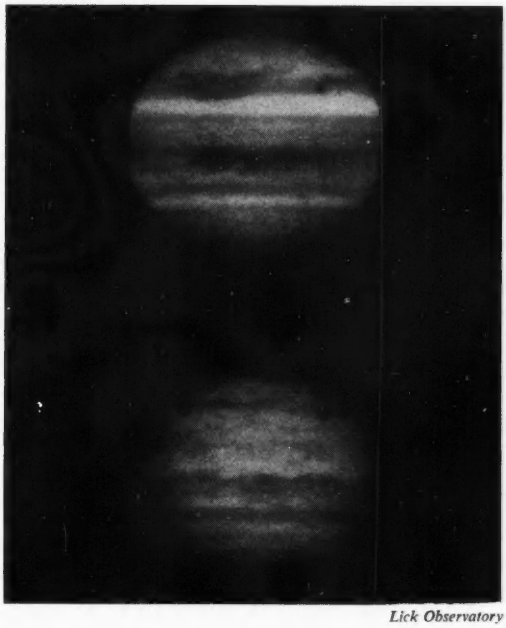
The universe being on so vast a scale, the question is inevitably suggested whether life is to be found elsewhere than on our own little Earth. Is the Earth unique in the whole of creation? I think that most people would find it difficult to believe that this can be so; for there to be but one home of life in the great universe seems such a waste of creation.

What has astronomy to say on this question? Though it does not provide a definite answer, we can get some evidence that at least suggests what the probable answer should be. It is not possible to discuss the question, however, without making certain assumptions. Suppose, in the first place, we could prove that there were other worlds where conditions resembled generally those on the Earth. Life could exist, of course, on those worlds but would it be legitimate to assume that, just as life has somehow come into existence on our own Earth, it would also have come into existence on the other similar worlds? There are many who take the view that life on the Earth is the result of a special act of creation and that only by a similar special act of creation could life come into being on any other world. If we accept this view, no further discussion is possible. On the other hand, we may take what seems to me the more rational view, that life somehow came into existence on the Earth because conditions were favourable for it; and that if elsewhere in the universe the conditions are favourable, there life will be found either now or in the future.

Composition of the Living Cell

Suppose, in the second place, we find that there are worlds on which conditions are so different from those with which we are familiar that no form of life to be found on the Earth could exist under them. Will it be legitimate to assume that such worlds must be devoid of life? It might be supposed that the forms of life that exist on the Earth have developed, through the slow process of evolution, in adaptation to those conditions and that on another world, where conditions are entirely different, types of life bearing no resemblance to any terrestrial forms might have developed. Living cells, of both plant and animal life on the Earth, though they show a diversity in structure all consist primarily of the elements carbon, oxygen, hydrogen and nitrogen; sulphur, phosphorus, potash, soda, lime and other substances may be present in smaller quantities. It is con-

ceivable that on another world the living cells might have a different composition. They might, for instance, contain silicon in place of carbon and, as a result of this difference, they might be able to exist at temperatures high enough to destroy all terrestrial forms of life. I think that such a possibility must be ruled out. The same elements, subject to the same chemical laws, are to be found throughout the universe. Moreover, there is no reason why cells of such different composition should not exist on the Earth, yet we do not find them.



Lick Observatory

Fig. 1. *Jupiter, photographed in ultra-violet light (above) and in infra-red light (below). The markings shown are in each case atmospheric.*

"Complex and Fragile"

Assuming, then, that there must be a general uniformity in composition of the elementary cells, wherever life may exist, we have some justification for concluding that certain essential conditions are necessary for life of any sort to be possible. The molecular structure of all living cells is both complex and fragile. A molecule of the protein called albumen, for instance, is built up of seventy-two atoms of carbon, one hundred and twelve atoms of hydrogen, eighteen atoms of nitrogen, twelve atoms of oxygen and one atom of sulphur. Such complex structures are readily broken up. High temperatures are very effective in breaking up these complicated molecules. All forms of life that we know are very sensitive to heat and the surest way of killing any form of life is to subject it to a high temperature. We boil water of doubtful purity because germs, which may be resistant to many destructive agents, cannot long survive at the temperature of boiling water. The more complex the form of life the more susceptible it becomes to any destructive agency because, if the protoplasm of essential cells is destroyed, the proper functioning of the organism is upset and the death of other cells, and eventually of the whole organism, as a rule results.

Low temperatures are also effective in destroying life, though some forms of life can withstand extreme cold for long periods. In such cases, however, there seems to be a state of suspended animation, in which all vital processes cease until the temperature is raised. Life becomes arrested or latent; the chemical structure is uninjured but chemical change is stopped. We cannot conceive that, if such conditions prevailed on any world, life could develop. There cannot possibly be development if all vital processes are suspended. We can therefore conclude that a world where there is a very high or a very low temperature is unlikely to be the home of any sort of life.

Satisfactory conditions of temperature are not in themselves sufficient. A further essential condition would seem to be the

presence of water, either in the liquid form or as vapour. It is by imbibing water containing the chemical substances on which they feed that cells grow and divide. Neither seeds nor spores will germinate in soil that is devoid of moisture, and water is an essential constituent of the tissues of both animal and vegetable life. In the absence of moisture life, when not actually destroyed, becomes latent. Most forms of life with which we are familiar are dependent for their activity upon the presence of free oxygen, though the absence of oxygen does not seem to be necessarily fatal to every form of life. Carbon dioxide is favourable for the existence of vegetable life. Many other gases are poisonous to life: ammonia, chlorine, carbon monoxide and sulphuretted hydrogen all have a marked toxic action. Though their presence in the atmosphere of any world would not necessarily prove conclusively that there could be no life on it, it would provide some evidence against its probability.

The presence in the atmosphere of any world of water-vapour, oxygen and carbon dioxide would therefore be evidence in favour of the possibility of the existence of life; the absence of these, combined with the presence of poisonous gases, would be evidence against the possibility of its existence. The absence of any atmosphere would necessarily be conclusive proof that life could not exist.

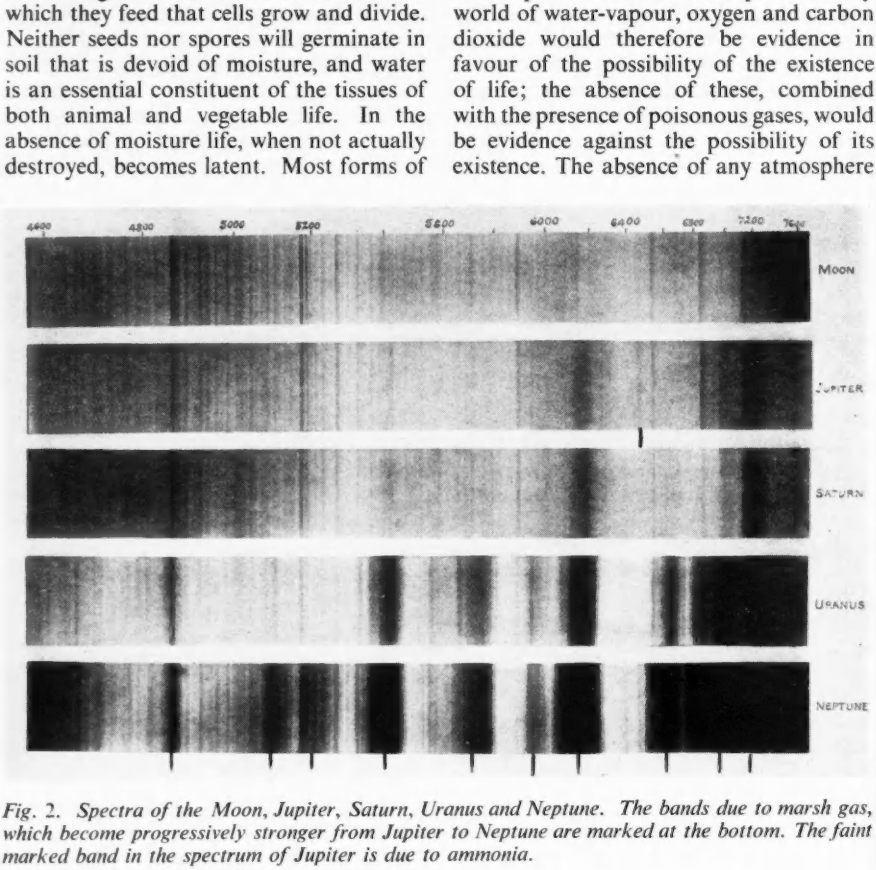


Fig. 2. Spectra of the Moon, Jupiter, Saturn, Uranus and Neptune. The bands due to marsh gas, which become progressively stronger from Jupiter to Neptune are marked at the bottom. The faint marked band in the spectrum of Jupiter is due to ammonia.

We can at once rule out of consideration the Sun and all other stars. The temperatures of the coolest stars are so high that only the simplest compounds can exist in their outer layers. The complicated molecular structures of living cells would inevitably be broken up at these high temperatures, so that no life could exist. Our search for the possibility of the existence of life must therefore be directed to the cooler bodies—

the planets and satellites, associated as in our solar system with a parent sun. But there we come up against the difficulty that the stars are so distant that any planetary systems they may possess are far beyond the reach of our most powerful telescopes. We cannot hope to see them; still less can we hope to learn anything about their temperatures and atmospheres. All that is possible is to study in detail the planets in the solar system and then to consider what general conclusions may be drawn from this information, supplemented by general considerations.

Atmospheres of the Planets

The quest is not altogether hopeless, for we can measure the temperatures of the planets by means of sensitive instruments, such as the bolometer, and we can learn something about the constitution of their atmospheres by spectroscopic examination. The planets are not self-luminous: we see a planet by means of light from the Sun that has fallen upon the planet and has been reflected or scattered back. Suppose a planet has an atmosphere: the light by which we see it started from the Sun, penetrated to a greater or less extent into the planetary atmosphere, reaching possibly, though not necessarily, the surface of the planet, and then came out again. This light will differ from the light that we receive directly from the Sun, because of the absorption of certain wave-lengths in the atmosphere of the planet. By comparing the spectrum of sunlight with the spectrum of the planet's light, we may hope to identify the absorption produced by the planet's atmosphere and to be able to assign its origin. But a complicating factor is produced by the atmosphere of the Earth, through which we view both the Sun and the planet. Absorptions occur also in this atmosphere, produced by water-vapour, oxygen, ozone, carbon dioxide and other substances. We can identify in two different ways the absorptions in the spectrum of the Sun that originate in the Earth's atmosphere. If we compare the spectra of the east and west limbs of the Sun with that of the centre of the disk, absorption lines originating on the Sun will be slightly displaced in the spectra of the limbs, and in opposite directions for the two limbs, with respect to the corresponding lines in the spectrum of the centre of the disk; this is merely an effect due to the rotation of the Sun. Lines originating in the Earth's atmosphere will occupy the same position in all three spectra. The second method is to compare the spectra of the Sun photographed at different altitudes. The lower the altitude, the greater the length of the path of the light through our atmosphere and the greater, therefore, the absorption produced by the atmosphere.

The spectrum of the planet may show some absorptions that are not to be found in the spectrum of the Sun, and other absorptions that are present in the spectrum of the Sun but that are known to be of terrestrial origin. The former can be attributed at once to the atmosphere of the planet; the latter may or may not be produced by the atmosphere of the planet as well as by our own atmosphere. We can endeavour to distinguish between the two possibilities by photographing the spectra of the Sun and the planet when the two bodies are at the same altitude and comparing the intensities of the absorptions.

If they are stronger in the spectrum of the planet relatively to absorptions of solar origin, there must be absorption in the planetary atmosphere superposed on absorption in our atmosphere. The principle is simple but its application is not always easy.

Velocity of Escape

The most detailed information about the constitution of planetary atmospheres can be obtained by observations at an observatory on a mountain or high plateau. Most of the information that we possess has been derived from observations at the Mount Wilson Observatory, and at the Flagstaff Observatory, Arizona.

We can infer something, however, about the atmospheres of the planets without

making any observations at all. A planet can retain an atmosphere only by virtue of its gravitational pull. If we could imagine our globe to be suddenly annihilated, leaving the atmospheric shell undisturbed, the atmosphere would rapidly dissipate into space. It is the gravitational pull of the Earth that prevents this dissipation. A rocket shot off from the Earth will be drawn back by the force of gravitation unless the velocity of projection exceeds 7 miles a second. This critical velocity is called the *velocity of escape*. For any other planet the velocity of escape will have a different value, the square of the velocity being proportional to the mass of the planet and inversely proportional to the radius. Because, as we shall see, this velocity is a very important criterion, the values for several bodies are tabulated:

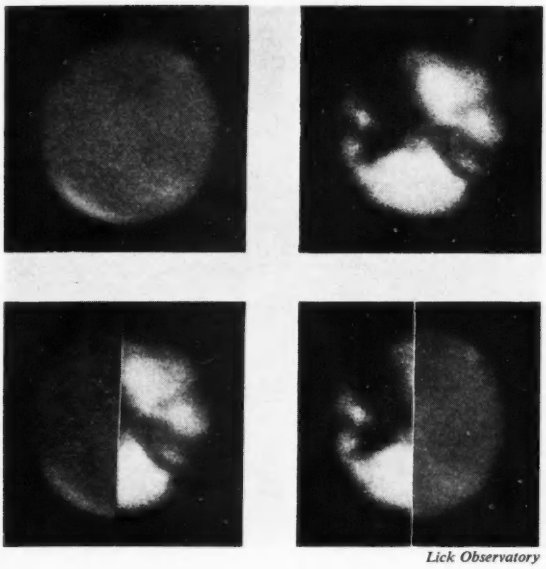
Moon	1·5	miles per sec.
Mercury	2·2	,, ,,
Venus	6·5	,, ,,
Earth	7·0	,, ,,
Mars	3·1	,, ,,
Jupiter	38·0	,, ,,
Saturn	23·0	,, ,,
Uranus	13·0	,, ,,
Neptune	14·0	,, ,,
Sun	386·0	,, ,,

In every cubic inch of the air that we breathe there are some five hundred million billion minute particles called molecules, flying about rapidly in all directions and continually colliding with each other. The lighter the molecule the higher is its average speed. The average speed of a molecule of hydrogen is $1\frac{1}{4}$ miles a second, whereas the average speed of a molecule of oxygen or nitrogen is not much greater than $\frac{1}{4}$ mile a second. Consider what is happening at the top of the atmosphere; there will frequently be molecules that rebound after a collision with a speed several times as great as the average speed. Suppose hydrogen molecules are present: the speed of some of these might well exceed 7 miles a second, the velocity of escape from the Earth. If they happened to rebound in a direction away from the Earth, they will escape from the Earth's gravitational pull, unless they should happen to collide with some other molecule. A slow escape of hydrogen from the outer layers of the Earth's atmosphere would therefore be expected. The atmosphere of the Earth, in fact, contains little or no hydrogen, the reason being that it has gradually slipped away into space. For nitrogen and oxygen, on the other hand, the velocity of escape is more than twenty times greater than the average speed of the molecules. Velocities so much greater than the average will rarely be reached, so that oxygen and nitrogen are held prisoners by the invisible but powerful bonds of the Earth's gravitation.

The Atmosphere of the Moon

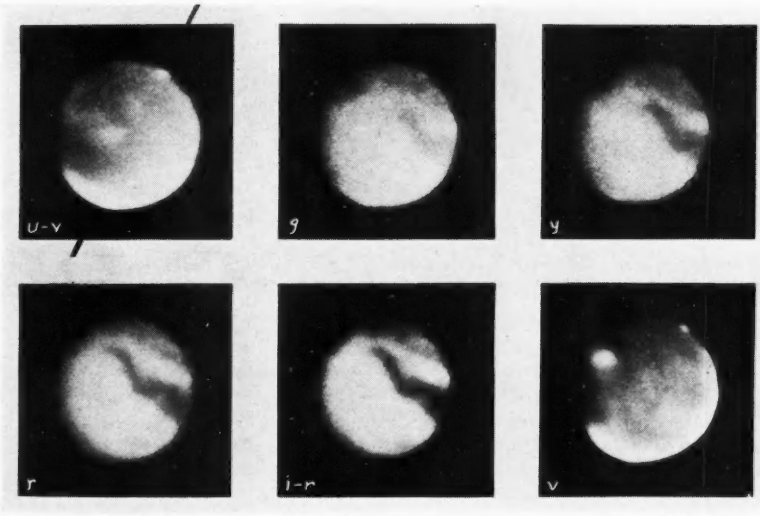
Now contrast the Moon and Jupiter with the Earth. It is rather more difficult for the Moon to hold an atmosphere of oxygen and nitrogen than it is for the Earth to hold an atmosphere of hydrogen. The Earth has existed long enough to lose its hydrogen and so we may anticipate that the Moon has lost not merely hydrogen but also oxygen, nitrogen, and water-vapour and that it may be entirely devoid of atmosphere. The velocity of escape from Jupiter, on the other hand, is so high that it is impossible even for hydrogen, the lightest of all substances, to be lost. We may accordingly expect to find a very extensive atmosphere on Jupiter.

These expectations are fully confirmed by observation. The startling suddenness with which a star disappears when the Moon passes in front of it, or occults it, proves that there can be no atmosphere. If there were any atmosphere, the light from the star would be refracted through it and the star would disappear gradually. The Moon is the nearest to us of the heavenly bodies and its surface can be studied in considerable detail. We see mountain ranges; many ring-shaped mountains, both small and large; great plains; and narrow cracks or fissures in its surface.



Lick Observatory

Fig. 3. Photographs of Mars in ultra-violet light, showing atmosphere (left) and in infra-red light, showing surface (right). Opposite halves are juxtaposed below, to show larger size of ultra-violet image, due to the considerable depth of atmosphere.



Lick Observatory

Fig. 4. Photographs of Mars in ultra-violet, green, yellow (above), red, infra-red and violet (below). The surface details become progressively clearer with increase in wave-length of light. The rotation of the planet (the direction of the axis indicated in the first image) causes the dark markings to move across the disk. The cloud, shown faintly near the centre of the disk in the first image, is beginning to form near noon; in the last image, it is well shown near the limit, having become strong by the late afternoon.

But there are no oceans, lakes or rivers; if these ever existed on the Moon, they have gradually evaporated and the water-vapour has dissipated into space. If there were a lunar inhabitant equipped with a powerful telescope, he would be able to see many signs of human activity on the Earth. No signs of the activities of lunar inhabitants are to be seen on the Moon; it is a dead world, without any atmosphere and without any water and therefore entirely devoid of life.

The Planets

Jupiter. The appearance of Jupiter is far different. We see markings in the form of bright patches and dark patches, arranged for the most part in belts parallel to the equator. At first sight, these markings might be thought to be surface features. But further examination shows that they are continually changing and that the appearance is never twice the same. All that we can see on Jupiter are cloud formations; we can never penetrate to the solid surface of the planet. Analysis by the spectroscope of the light from Jupiter reveals an atmosphere very different from our own. We can find no trace of oxygen, nor of carbon dioxide, nor of water-vapour. The absence of water-vapour is not to be wondered at, for when we measure the temperature of Jupiter we find it to be about -200°F., so that any moisture would be precipitated as ice or snow. The prominent features of the spectrum of Jupiter are strongly marked absorptions characteristic of ammonia and of marsh gas, the poisonous gas that the miner knows as fire-damp.

Strange though an atmosphere containing pungent ammonia and poisonous marsh gas may seem, it is precisely the type of atmosphere that might have been predicted. Jupiter, in common with the other planets, was formed from matter ejected by the Sun. The Sun consists largely of hydrogen and Jupiter, when it was first formed, must also have contained a large proportion of hydrogen. The great gravitational pull of Jupiter prevented this hydrogen from escaping. As Jupiter cooled, the oxygen in its atmosphere combined with some of the hydrogen to form water-vapour and this, with further cooling, was deposited on the surface as a thick layer of ice. Nitrogen and carbon also combined with some of the excess hydrogen to form saturated compounds. The most volatile compounds of hydrogen with nitrogen and carbon are ammonia and marsh gas respectively, and these are the gases that we should expect to find in the atmosphere of Jupiter. We infer also, though we cannot test it by observation, that there must be a great deal of hydrogen in the atmosphere. A poisonous atmosphere, containing neither oxygen, carbon dioxide, nor moisture, combined with an extremely low temperature, must make any form of life quite out of the question.

The other large planets, Saturn, Uranus and Neptune, can be briefly disposed of. Being more distant from the Sun than Jupiter, their temperatures must be appreciably lower. For the planets have no residual heat of their own. There is a balance between the heat they receive from the Sun and the heat they radiate back into space. The farther from the Sun a planet is, the less is the heat that falls on unit area of its surface; the lower, therefore, must be the average surface temperature. These three planets are all sufficiently massive to have retained their hydrogen; marsh gas is a prominent constituent of all their atmospheres, but ammonia becomes less prominent as, with an increasing degree of cold, it is frozen out of the atmosphere. The temperature of Neptune is so low that nitrogen could only exist on it in the solid state. We need not look for life on these distant frozen wastes.

Mercury. Returning to the nearer planets, it will be noticed that the velocity of escape from Mercury is not much higher than that from the Moon. Mercury always turns the same face to the Sun, so that one hemisphere has perpetual day and the other has perpetual night. The sunlit face is intensely hot; where the Sun is overhead it is as hot

Barnard

Fig. 5. Small star-cloud in Sagittarius, showing large number of stars in Milky Way regions

as a bath of molten zinc. This high temperature would facilitate the escape of any atmosphere, because the higher the temperature the faster the molecules move. We must conclude that Mercury, in common with the Moon, is devoid of any atmosphere and is a dead, arid world. The surface of the planet shows nothing more than extremely faint markings, only observable with great difficulty: it is probably a uniform plain, with no very distinctive features.

Venus. Venus and Mars have special interest and require more detailed consideration. Venus is the planet most nearly equal to the Earth both in size and in weight. The velocity of escape from Venus being nearly the same as from the Earth,

we expect to find an extensive atmosphere on Venus, though the hydrogen will have escaped. The telescope confirms this, for we find Venus to be covered with a dense permanent layer of clouds, which entirely obscures her surface. Faint, ill-defined markings are sometimes seen, but they have no permanence.

There has been a great development in recent years in the use of photographic plates sensitive to the infra-red light, the light of long wave-length to which the eye is not sensitive, for the photography of distant landscapes, because the infra-red light is able to penetrate haze or fog much more easily than the light of short wave-length, the blue, violet and ultra-violet light to which ordinary photographic plates are sensitive. Venus has been photographed using these infra-red-sensitive, or haze-cutting plates in the hope that something of her surface might be revealed. But such plates show no more than our eyes can see. The cloud layer is too thick.

The temperature of Venus has been measured. The temperature of the sunlit face reaches 80° or 90° F., whilst that of the dark face falls to about 40° below freezing point. Venus has a long day; its length is not known exactly but it is somewhere about thirty of our days. This explains the great difference between the midday and midnight temperatures on Venus. The temperatures on the surface of Venus, below the permanent layer of cloud, are likely to be appreciably higher than the measured temperatures. The temperature conditions on Venus are certainly not such as to make life impossible.

What about her atmosphere? No evidence of the presence of either oxygen or water-vapour has been found. The tests for oxygen are very sensitive; those for water-vapour are less sensitive, but the failure to detect the presence of water-vapour is surprising because the clouds on Venus must almost certainly be clouds of water-vapour, similar to the clouds in our atmosphere. The explanation is probably that the atmosphere above the cloud layer is pretty dry. There may be a very humid atmosphere below the clouds. One important fact has been established—an abundance of carbon dioxide, very greatly in excess of the amount in our own atmosphere, is present in the atmosphere of Venus.

The scarcity of oxygen, combined with the abundance of carbon dioxide, provides a clue to the conditions prevailing on Venus. On a cooling planet of the size of Venus we should expect to find both water-vapour and carbon dioxide evolved from the molten rocky mass as it cooled and solidified. We should not expect to find oxygen, because oxygen is a chemically active element and does not like to exist alone. The surprising thing is not the absence of oxygen in the atmosphere of Venus, but the abundance of it in our own atmosphere. The oxygen is continually being depleted from our atmosphere by combining with other substances and there must be a source of replenishment. This is undoubtedly provided by the vegetation on the Earth's surface, which extracts carbon dioxide from the air and uses the carbon for building up the plant cells, giving out oxygen. The supply of carbon dioxide is in turn replenished by processes such as combustion, respiration and the decay of vegetable matter. When life started on the Earth there was probably plenty of carbon dioxide but comparatively little oxygen in the atmosphere. We seem to see in Venus a world where the conditions are somewhat similar to those that the Earth passed through millions of years ago. Any life on Venus can be at the most primitive plant life. It is possible that life may be in process of gradual development and that in the millions of years to come, when life on the Earth may be nearing extinction, Venus may be the home of higher and higher types of life.

Mars. The last of the planets to be considered is Mars, the most interesting of all the planets. In the telescope it appears as a beautiful orange-coloured object, on which misty dark markings can be seen.

Mt Wilson Observatory

Fig. 6. Nebula in Coma Berenices, a stellar universe seen edgewise on

These markings are permanent, and we see them carried round as the planet rotates in a day that is some 40 minutes longer than our day. Careful observation shows that these markings undergo changes, both of form and of coloration, which are in part seasonal in character. Around whichever pole is visible there is seen a bright white cap; the two polar caps show regular seasonal changes in size, growing in the

winter and shrinking in the summer. Their appearance suggests something similar to the regions of ice and snow around the poles of the Earth, though from the rate at which they melt as the summer advances it can be inferred that the Martian polar caps are not more than a few inches in thickness.

There has been much controversy over the existence of the so-called canals on Mars, a geometrical network of perfectly straight, narrow and sharply defined lines connecting up the dark markings, which some observers claim to have seen. The American astronomer, Percival Lowell, built up a romantic theory about these canals. He regarded them as irrigation channels, carrying water to the dark regions or oases from the melting polar caps. His conclusion was that the canals were artificial structures, made by a race of intelligent Martian beings, who were engaged in a desperate struggle for existence on a semi-arid planet. Lowell's geometrical network of sharply defined canals has not been confirmed, however, by the most keen-sighted observers, with the largest telescopes, observing under the most favourable conditions. It seems that they are an illusion of vision, arising from a psychological tendency for the eye, when looking at something that is almost at the limit of vision, to connect up detail by narrow lines to form a geometrical pattern. We must abandon Lowell's theory. What is certain is that we can see markings on the surface of Mars, and that these undergo seasonal changes, which seem to indicate the seasonal growth of vegetation.

Proofs of an Atmosphere

The low velocity of escape from Mars suggests that, if Mars has an atmosphere, it must be very tenuous. We obtain direct proof that it has an atmosphere by taking photographs in infra-red and ultra-violet light. The infra-red photographs show the surface markings clearly; the ultra-violet photographs do not show them at all. The scattering of the ultra-violet light by the atmosphere is enough to prevent it penetrating to the surface and out again. The images in ultra-violet light are larger than those in infra-red light, and a comparison of them shows that the atmosphere has a considerable depth—not less than 50 miles. Comparison with terrestrial photographs taken under favourable conditions suggests, nevertheless, that the total atmospheric pressure on Mars does not amount to more than a few per cent. of that at the surface of the Earth.

Another proof of an atmosphere on Mars is the appearance of clouds. These are of two kinds. Some are shown clearly in the ultra-violet photographs and not in the infra-red; such clouds must be high up in the atmosphere and sufficiently thin to allow the infra-red light to pass through. Other clouds are seen in the infra-red and not in the ultra-violet photographs; they must be low-lying clouds of water-vapour, seen through a yellowish atmosphere.

Endeavours to detect oxygen and carbon dioxide in the atmosphere of Mars have so far been unsuccessful, and it can be concluded that the amounts of these gases in the Martian atmosphere are less than one-tenth of 1 % of the amounts in our atmosphere. Water-vapour must undoubtedly be present for, although there are no open seas on Mars, the polar caps must be caps of ice or snow. Water-vapour has been detected, in fact, at the Lowell Observatory, by comparing the spectra of Mars and the Moon at the same altitude, under conditions of exceptional atmospheric dryness. The reddish colour of much of the surface of Mars is probably due to the oxidation of iron-bearing ores by atmospheric oxygen and is in marked contrast to the grey unoxidized rocks on the Moon. It is probable that there is still a little, though not much, oxygen in the atmosphere.

The extreme tenuity of the Martian atmosphere is responsible for great diurnal variations of temperature; a scanty atmosphere, with very little moisture in it, does not have much blanketing effect. Near noon, in the equatorial regions, the temperature rises to about 50° F.; but in the

afternoon, as the Sun gets lower, the temperature falls rapidly. After sunset the cold becomes intense and the minimum temperature at night is about 130° below zero. With such an enormous daily range of temperature, the conditions for any form of life must be very trying. Whether animal life can exist seems doubtful, though it is impossible to assert that life may not have evolved to suit those conditions. In Mars we see a world where conditions resemble those that will probably prevail on our Earth many millions of years hence, when most of our present atmosphere will have been lost. Mars appears to be a planet of spent or nearly spent life.

This brief survey of the planets in the solar system has not given any clear indication of life elsewhere than on the Earth, with the probable exception of some vegetation on Mars. It seems that Mars is a planet where life may be on the verge of becoming extinct and that Venus is a planet on which life may be on the verge of coming into existence. Elsewhere there is no life of any sort.

Planets in other Systems

But what is the likelihood that other stars have planets associated with them and that life may exist on some of these? To assess the probability that other stars have systems of planets we must be able to account for the origin of the solar system. This is one of the most difficult problems in astronomy, which has not yet been completely solved in a satisfactory manner. The only hypothesis which seems to account for the facts is to suppose that a few thousand million years ago another star passed close to the Sun. The passage of the star raised a great tidal protuberance on the Sun, which became greater and greater until a long jet of matter was drawn out. As the stranger star passed on its way, the tidal wave on the Sun subsided but the matter drawn out from the Sun broke up and condensed into planets. The stars are so far apart that such a close encounter of two stars can rarely happen; calculation suggests that it may occur about once in five thousand million years. Hence planetary systems are not the rule, but very much the exception, and in our stellar universe there can be but few stars, in addition to the Sun, which have systems of planets attached to them.

In any planetary system, everything seems to be weighted against the possibility of the existence of life. If the planet is too near its parent sun, it will be too hot for life to exist; if it is too far away, it will be too cold. If it is much smaller than the Earth, it cannot retain any atmosphere. If it is much larger, it will have retained too much atmosphere, for when hydrogen cannot escape the formation of the poisonous gases, ammonia and marsh gas, appear to be almost inevitable.

"It seems probable that there are other worlds where life exists"

Amongst the vast number of stars in any one stellar universe, we should expect to find only a limited number with a family of planets; and amongst these families of planets there cannot be more than a small proportion where conditions exist that make life possible. On the other hand we must remember the vastness of creation; there are about one hundred million separate universes in the region of space accessible to observation, and we know not how many more beyond. If in each universe there are not more than two or three dozen stars with families of planets, the total number of planetary systems within the relatively small region of space that we can survey is immensely great. If the proportion of planets on which life can exist is not more than one in a million—and our survey of the solar system suggests that this is a considerable underestimate—the total number of planets where conditions are suitable for life must be considerable. So it seems probable that there are other worlds where life exists, though that life may be entirely different from any form of life with which we are familiar.

Reviews

Ascaris: The Biologist's Story of Life

PROFESSOR GOLDSCHMIDT, the distinguished geneticist, has written a book on *Ascaris*,* a parasitic worm inhabiting the intestines of man and animal. But the little creature is merely a pretext to bring before the reader in three hundred pages aspects of life as different as "Form and Colour", "Nervous System", "Fertilization and Heredity", to name only some of the chapter-headings. A detailed index of nearly 1000 entries includes such items as diabetes, fermentation, Apollo, the effect of slums. The book is fully illustrated, and includes pictures of the stomach of a sheep, sections of the thighbone, a vertebrate embryo and a negro leg demonstrating the black races' peculiar Achilles tendon. As the author writes: "*Ascaris* manifests physical characteristics not so very different from those of your goldfish, your canary, your dog and yourself. He adapts himself to his environment, he is concerned with food and lodging and the propagation of his kind. Through *Ascaris* the whole amazing story of living creatures can be told." The book is addressed to everyone; the adolescent boy or girl, the adult layman, the young student, or the mature professional man. It is a story of life told thrillingly and without sensationalism; pleasant to read, and at the same time accurate and exact.

When reading the title, *Ascaris: The Biologist's Story of Life*, I cannot help recalling an episode of the biologist Goldschmidt's life. On visiting him in April 1936 I found the Professor on the point of leaving to take up his present post at the University of California. He was in a room of his former institute in the Berlin suburb, Dahlem, which his work had helped so much to make known throughout the world. Professor Goldschmidt was packing his collection of Chinese antiques. He was surrounded by boxes, and half buried under straw, old newspapers and sawdust. Nobody was allowed to help him as only he himself could undertake the difficult task of changing the precious masterpieces of ancient artists into objects to be handled by porters and ship's cranes. Reading the book on *Ascaris* I saw again the skilled hands at work transforming delicate intricacies into simple freight. But whereas the beauties of the china were hidden by this procedure, the splendour of biology shines the brighter and warmer.

H. LEHMANN

* *Ascaris: The Biologist's Story of Life*, by Richard Goldschmidt. The English University Press. 10*s*. 6*d*.

Sand and Sea in Arabia

NORMAN LEWIS is responsible for the pictures and the writing in this unusual travel book† (an enormous number of illustrations, 123 of them, with comparatively little text), and he is so much more admirable as a traveller and writer than as a photographer that one longs for more description of this journey—or indeed of any other journey that he has ever made—instead of quite so many under-exposed plates, cut and tilted self-consciously, sometimes on the fuzzy-artistic edge of being out of focus.

Whenever he is up against time in taking pictures the results are superb. There are impressions of an Arab marriage-feast, with his fellow-guests unaware of the camera; a gang of men lifting a heavy load; the brief twilight of the Red Sea; a dhow sliding past while a grand negro figure stands in outline for a second against the

† *Sand and Sea in Arabia*, by Norman Lewis. Routledge. 15*s*.

From "Sand and Sea in Arabia"

sail: and these are some of the finest photographs I have seen. It is only when the subject allows for leisure that he presents a monotony of what I glumly suspect to be Significant Form, since it looks just as well the other way up. It is odd that anyone who can photograph brilliantly under difficulties should be so persistently pleased

K. Herschel

Common Morel

With a page for every week, this calendar is a collection of 60 excellent photographs of birds, mammals, trees and flowers, and includes, among others, the names of such well-known nature photographers as E. J. Bedford, Frances Pitt, Niall Rankin, Eric Hosking, John Markham, and K. Herschel, whose "Common Morel" is reproduced above. Each beautiful photograph is accompanied by a short descriptive paragraph.*

* The Naturalist's Calendar, *edited by Phyllis Barclay-Smith and Rudolf Zimmermann,* (*M. C. Forrester.* 3*s.* 6*d.*)

by the discovery that all detail may be eliminated from dark-skinned faces by posing them against a fierce light.

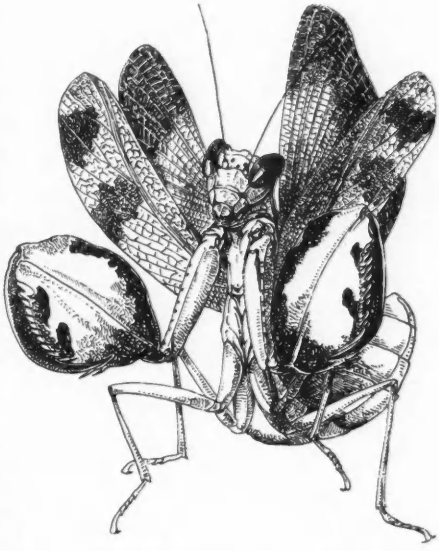
It is the odder because, as a traveller, he is so excellently free from self-consciousness. Everything is taken as it comes, and it comes to him in good measure as he journeys slowly from the Yemen through southern Arabia and up the Red Sea in a dhow, among a variegated group of passengers: the glimpses of beauty, the smells and dirt and richness of these old lands, and the insight into alien lives (only nothing seems to be alien to him). Even I, who feel a personal venom towards the Red Sea, had a positive nostalgia for that uncomfortable dhow by the time it deposited him at Suakin, and believe that I know its crew better than I could have done had I made that journey in the flesh, as well as much more pleasantly.

The story is told only in caption-paragraphs under the pictures, which gives the book an unorthodox form; but Mr Lewis throws off such fascinating references and asides, having no chance to follow them up by this method, that it is to be hoped he will let himself go more thoroughly in print next time (encouraged by the fact that it must be extremely rare for any reviewer to ask for less to look at and more to read!). E. ARNOT ROBERTSON

La Biologie des Orthoptères

OF the profusion of figures in this important book* two show heads of the Stick insect familiar in vivaria: *Carausius morosus*, with a leg growing where an antenna should be, and a Mexican tree cricket, *Salona*, with a tarsus growing out of the top of the femur. These are striking abnormal instances of the phenomena of self-amputation and regeneration, of which the various categories, the mechanism and effects are described by the author. It is the discussion of such phenomena, their description, illustration and the full bibliography that lift this work out of the restricted sphere of the specialist and endow it with an appeal not only to entomologists, but to all biologists. In it the reader will find reasoned accounts not only of the life and habits of the Orthoptera, but of their reactions to external stimuli, homochromism, mimicry, variation, heredity and many other problems. In describing the so-called methods of defence, such as threatening attitudes, spitting, chirping, fluttering, extrusion of foam and, oddest of all, the squirting of caustic blood, M. Chopard, who declines to accept the principle of utility, explains them all by simple reflex action.

The author is very sceptical about the current explanation of the brilliant wings



of certain grasshoppers. About fifty years ago Jenner Wei suggested that the flash of the crimson wings of the red underwing moth during a short flight serves to distract the attention of a pursuer, so that directly the insect settles, its procryptic coloration hides it, and the enemy continues to hunt for something red. Whether or not this is a complete explanation, it does as a

* *La Biologie des Orthoptères*, by L. Chopard. Lechevalier, Paris. 265 fr.

matter of fact occur in nature, as I have repeatedly observed. In my camp in Northern Rhodesia the ground was so trodden that there was no vegetation left, only dusty earth. This was frequented by little grasshoppers of the genus *Acrotylus*, which harmonize perfectly with the ground when settled, but expose crimson wings when flying. Over and over again I was amused to see my chickens race eagerly along after the red flash and then, when the insect vanished into the dust at their feet, stand still and crane their necks comically and look all round, obviously seeking something red. It is certain that the red flash had a survival value for those *Acrotylus*.

The book has surprises for those unfamiliar with the byways of orthopterology. That queer creature *Grylloblatta*, a link between cockroaches and crickets, which is known from the mountains of Canada, California and Japan, can live only at a temperature a little above freezing, and in captivity must be packed in ice. This is the more extraordinary, in an order so dominantly thermotropic as the Orthoptera. Over 600 species of cockroaches are known from the Palaeozoic. The common cockroach, *Blatta orientalis*, generally considered to have been introduced to Europe after the discovery of America, has been found in the diluvium of Schleswig-Holstein.

Very interesting is M. Chopard's account of the orthopterous fauna of European caves. These curious creatures he regards not as specialized for cave life, but as survivors of an ancient fauna since destroyed by the glaciers, and which have found refuge in the caverns. It is astonishing to learn that a drawing of Magdalenian age that can be recognized as belonging to *Troglophilus*, a genus of crickets known to-day only from caverns in the Aegean area, has been found in a cave in Ariège.

MALCOLM BURR

Select List of Books Received by *Discovery*

(*Mention in this list does not preclude review*)

Borneo Jungle. TOM HARRISSON and others. (Lindsay Drummond, 15*s*.)

The Story of the Road. J. W. GREGORY. (Black, 7*s*. 6*d*.)

Ghosts and Apparitions. W. H. SALTER. (Bell, 3*s*. 6*d*.)

Wild Animals in Britain. FRANCES PITT. (Batsford, 8*s*. 6*d*.)

Seen in the HadhRamaut. FREYA STARK. (Murray, 21*s*.)

Australian Parrots. NEVILLE W. CAYLEY. (Angus and Robertson, 15*s*.)

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